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INDUSTRIAL SERIES

INDUSTRIAL DRAWING

BY

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Prepared under the Direction
of the Division of Engineering Extension
THE PENNSYLVANIA STATE COLLEGE

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INDUSTRIAL DRAWING

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FOREWORD

This volume is one of a series of texts prepared by members of the staff of the School of Engineering of The Pennsylvania State College. While these books may be of value in college teaching and elsewhere, they are intended for use in adult teaching.

Experience in extension service indicates that there is a great lack of teaching materials suitable for the instruction of adult classes. Such extension classes at The Pennsylvania State College are composed of individuals who wish to study material which has fairly direct application. This is particularly true of students who are working in industry who carry on part-time study, as well as others who are preparing for jobs in industry. A common school education may make up the entire formal schooling of many of these students. Such students qualify by reason of self-education in many cases and by experience in industry which constitutes a valuable apprenticeship.

Extension instructors are selected on the basis of their practical experience in a particular field as well as on the basis of their academic preparation. Text materials used in such classes should therefore be readable, understandable, and "practical."

The author of this volume on Industrial Drawing, H. R. Thayer, Assistant Professor of Engineering Drawing in the Department of Architecture in the School of Engineering, brings to his task a wealth of experience in campus teaching and in extension instruction as well. He has published other text materials. This book is prepared, therefore, out of a rich background of practice. The book should constitute a valuable medium for teaching industrial drawing, particularly to adult students.

This Industrial Series will include texts on mathematics, blue print reading, engineering drawing, mechanics, strength of materials, machine design, electricity, and others. While some theory will be included, stress will be laid on the application of the principles of these subjects to important practical problems common in industry.

E. L. Keller, Director,
Department of Engineering Extension.

The Pennsylvania State College,
June, 1942.

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INDUSTRIAL DRAWING

INTRODUCTION

This book is written primarily as a text for those who wish to undertake the study of Mechanical Drawing; it is limited in its scope to such material and such amounts as the student can understand in the brief period usually allotted to the subject. There are already many good treatises on industrial drawing; we do not intend to compete with these. Indeed we recommend them as excellent supplementary material. Those who intend to become professional draftsmen will do well to purchase at least one of these; they are really encyclopedias of drawing and contain some information about the fundamentals of engineering.

It is hoped that enough will be learned from this volume so that the apprentice in the drawing room will make rapid progress in his work and that he will be able to appreciate, understand, and use the large amount of information contained in the conventional treatises on the subject.

While the text has been arranged to be used by regular classes, it is hoped that it will be especially useful to those who must study alone. For this purpose the explanations have been made direct and simple, yet as complete as is possible under the circumstances. It is expected that this same feature will assist those in classes who would otherwise fall behind if compelled to be absent. The book is so arranged that the work required of a student may be varied to correspond with his ability or perhaps to include the professional field in which he is interested.

Each lesson will contain sixteen questions, four sketches, one lettering exercise, and five sheets of drawings. From these the instructor should assign eight questions, two sketches, the exercise in lettering, and a sheet of drawing. This assignment may vary with the progress of the class, with individual interests, with the group ability or the ability of each student, as seems best to the instructor.

This work is arranged for 40 exercises of three hours. The lessons are expected to occupy six hours each, although it is realized that this will mean a great deal of effort and some overtime. A quiz should be given occasionally; possibly after the completion of the fourth sheet, the eighth sheet, the twelfth sheet, the fifteenth sheet, and the twentieth sheet. It would be well

if certain exercises were devoted to the examination of practical drawings, more particularly those of industrial concerns operating in the vicinity. Possibly one or two sheets of drawings might be added, based upon objects used or produced locally. Altogether, 50 three-hour exercises may well be used.

This course has two principal aims:

1. To enable men to make sketches or drawings that can be used by themselves or others.

2. To enable men to understand sketches or drawings so that they can make other drawings or sketches from them; order the necessary materials from drawings or sketches; estimate costs; make objects, inspect them, or supervise their making.

We communicate with one another in three ways: by speech, by writing, and by pictures. Each type has a field in which it is best and most suitable for conveying our meaning. In industrial work we use these same three methods. However, writing and pictures have especial importance because the instructions given in this manner can be preserved and duplicated, thus sending identical instructions to many persons and preserving and recording these instructions. The careful description of an object by written words is called "specifications," and the same task performed by pictures is called "plans" or "drawings."

The older way of manufacturing anything—a bridge, a building, or a machine—was to fit each part to the work already constructed. The modern method, commonly known as mass production, is to determine in advance the exact size and shape of each part. This enables a large number of men to work simultaneously on a machine or other object, each man producing a single part with equipment especially designed for the purpose. Thus, production is greatly increased and the cost is reduced. The method has the additional advantage that repairs and renewals of parts can be made quickly and cheaply.

An essential part of all production, and especially mass production, is carefully prepared specifications and drawings. Our attention will be directed toward the latter. Drawings for use in manufacturing may be divided into three classes. Each class is illustrated by its application to a small dwelling house.

A perspective drawing is a representation of an object as it appears to the eye. Here the size of anything varies, not only with its dimensions, but with its distance from the eye and the angle at which it is seen. The ordinary photograph is a perspective. There are mechanical methods by which a perspective may be drawn; they will be considered only briefly in this text. The upper sketch in Fig. *a* is a perspective.

An isometric or oblique drawing has a resemblance to a perspective, but it is much more easily constructed, and to a certain extent it is proportional.

Notice in the isometric drawing in Fig. *a* that parallel lines are parallel, instead of converging as in the perspective.

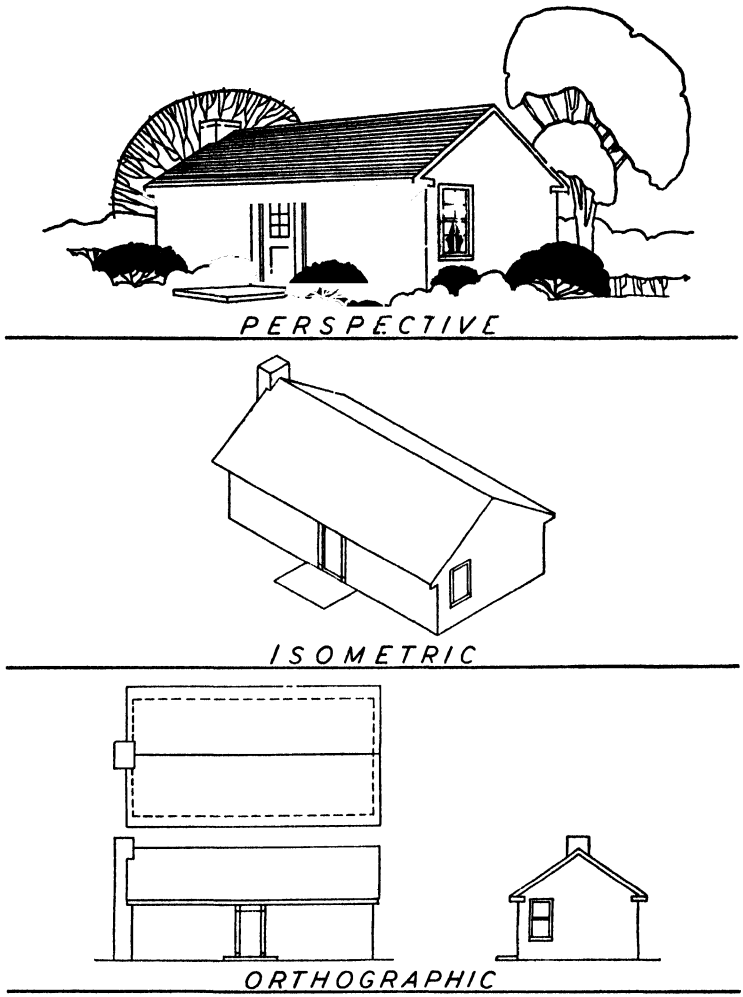


Fig. *a*.—Different classes of drawings.

An orthographic drawing may be regarded as a picture looking squarely at the main face of an object. To describe completely anything, two or more of these views are usually necessary. For example, the top view alone of a desk is not enough; it should be supplemented by a front view to show the heights of the desk and its parts.

For many miscellaneous purposes, the perspective drawing, looking

diagonally at the main faces, is ideal. However, for industry there are several objections to its use:

1. Angles are distorted and distances are not proportional.
2. If a dimension is placed upon the drawing, there is often uncertainty as to the points between which it extends.
3. There is considerable difficulty in making the drawing.

For these reasons the perspective is not often employed in business. Its main application is in preliminary building work where it is desired to show the general appearance of the proposed structure. The three objections given above hold to some extent for isometric and oblique drawings, and these are not often used in industry. Our main reliance, then, is the orthographic sketch or drawing; however, the pictorial drawings, that is, the perspective, the isometric, and the oblique, will be treated briefly.

CLEARNESS

Let us now suppose that a concern in Williamsport orders 100 machines from some company in Pittsburgh. The latter then prepares very careful orthographic drawings of the object to be sold. The draftsman draws the top view, the front view, and the side view, in each case looking squarely at a face of the machine. Many important lines will be hidden; these will be made with short dashes. Often these views are so complicated that additional views are necessary—a view of the rear or the other side. A view of an imaginary section cut down through the machine is frequently added to make the work clearer. Sometimes views at an angle are shown. The one important thing is that the draftsman must make clear beyond all question every last detail of the machine. The drawings must be understood by the head officials of the manufacturing company in Pittsburgh and of the purchasing company in Williamsport; and, above all else, they must be clear to the workmen who make the machines and set them up. Drawings that require explanations and those about which arguments arise are faulty.

ACCURACY

A great deal of value is attached in practice to the *correct* solution of a problem. An employee may know his subject thoroughly and be able to do his work very rapidly; however, it must be free from errors to be acceptable to his company. The superintendent and the foremen prefer men who are slow but accurate to those who are quick and talented but unreliable, although they seek especially men who have trained themselves to be both quick and accurate.

It is difficult for a student whose mind is endeavoring to grasp new principles to pay close attention to accuracy. Nevertheless, accuracy should

always be borne in mind. Blame yourself for every mistake that you make. You may expect that errors in your lessons will be criticized, often severely, by your instructor. Please realize, however, that his motive is not based upon anger or impatience, but is an effort on his part to lessen future errors and thus make you a more valuable worker. Constant attention to the points mentioned below, plus continual pressure to make your work accurate, will in time produce great improvement. Do not allow yourself to become worried or overanxious, because this is likely to make things worse rather than better.

It is believed that the following suggestions will prove helpful:

Read each question carefully. Every word means something.

Study each drawing until you understand it as far as the question is concerned.

Answer in figures and language that admit only the correct interpretation.

Pause a few seconds and be sure that this is the *right* answer.

Do this as quickly as you can and be sure that you are correct.

MAKING A DRAWING

In modern industry when work is to be done, it is carefully planned with the aid of drawings. These may show things as they are at present, or they may represent proposed construction. In many cases, both are seen in order that the effectiveness of the two in combination may be studied.

The drawing is first made in pencil; sometimes the pencil lines are inked to make it plainer.

The next step is to copy the drawing already made. Over the detail paper is laid a smooth, transparent sheet of tracing cloth. On this the drawing underneath is copied in ink.

DUPLICATION—PRINTING

Now many copies of this drawing of the plant will be needed for the use of the officials of the company. Any additional building or other improvement will be considered with the aid of this map.

Let us also consider the order that we have already mentioned for one hundred machines to be delivered in Williamsport. Many men will work on these machines—pattern makers, foundrymen, welders, machinists, shippers, erectors, and so forth. Many departments will be concerned, and each must have its copy of every drawing that shows any part on which it works. Also, the purchaser in Williamsport needs drawings for approval and perhaps for setting up and using his machines. Possibly 30 to 50 copies might be needed in an average case. There are several ways of getting these

copies, but the most common method for these and similar cases is to make blue prints.

The first requisite is that the drawing shall be made by opaque lines upon transparent paper; work in ink on tracing cloth meets this need. Then the drawing is placed in a glass frame with its face toward the light, usually an arc light. In back of this drawing is a chemically coated paper with the prepared surface also turned toward the light. In this situation the two stand for a short time, perhaps two minutes. In the shadow of the lines no change takes place, but elsewhere the light turns the chemical into a deep, permanent blue. Then the paper is taken out, washed, and later dried. In back of each line the chemical washes off, leaving the white of the original paper. The rest of the paper is blue; thus, we have the *blue print*: white lines on a blue background.

However, there are certain advantages to be obtained by a white background. Then the print looks more like a real drawing and it is easier to read changes, corrections, and notations that may be made upon it in pencil.

A *black print* may be made in the same manner as a blue print, except that a different paper must be used. The result is black lines on a white background.

RULES REGARDING LESSONS

All answers, lettering, and sketches are to be done on one side of 8½″ × 11″ cross-section paper.

Allow ample room in the margin and between answers for corrections and comments.

Give only the answers; the questions need not be repeated.

Pride yourself upon neat, well-arranged work. It takes little longer and it is much more efficient when others must use your drawings.

Every sheet containing answers, lettering or sketches should have, neatly lettered in the lower right-hand corner, your name, the lesson number, and the sheet number, thus:

RADFORD, Lesson 6, Sheet 2 of 4

The standard form and dimensions for the drawing sheets are as shown in Fig. *b*.

At the completion of the course, all sheets should be neatly bound together. Please place them in order—answers to questions for Lesson 1, sketches for Lesson 1, lettering for Lesson 1, and Sheet 1; then, answers to questions for Lesson 2, sketches for Lesson 2, and so on.

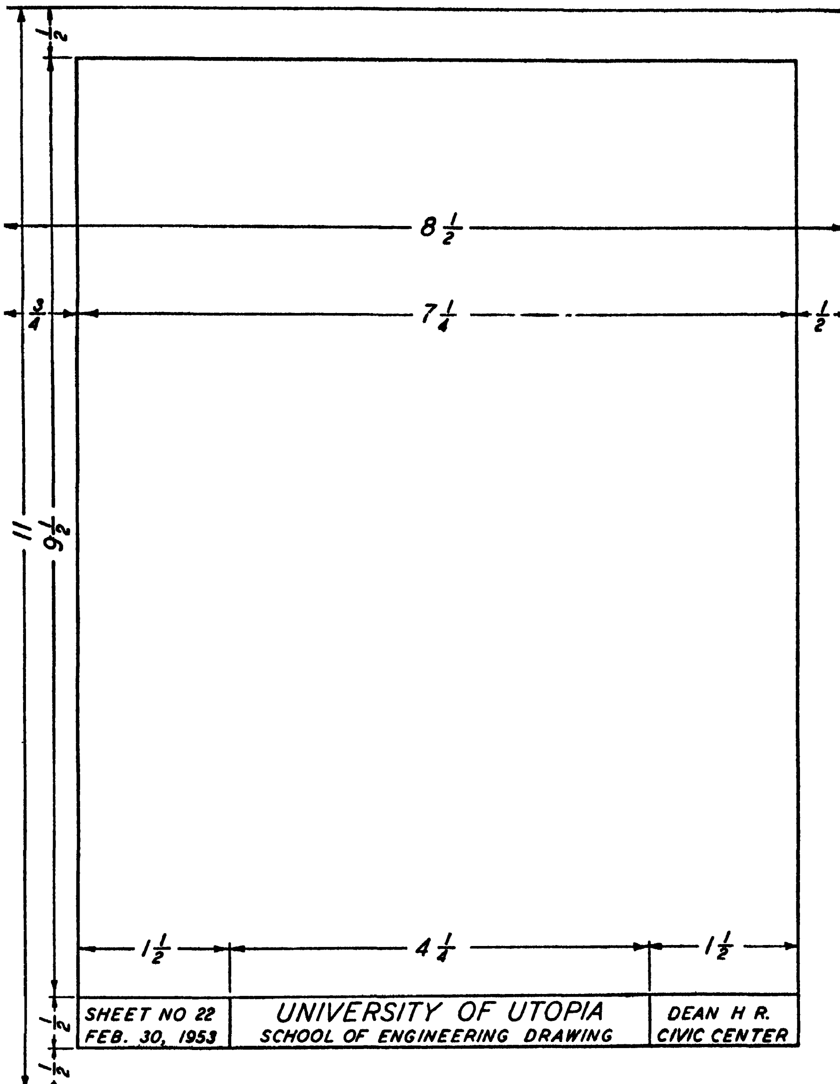


FIG. *b*.—Standard sheet.

MATERIALS REQUIRED

It will seldom happen that the student or the draftsman will possess complete equipment. Often he will be compelled to improvise an instrument or perhaps change some work to conform to what he has. On the other hand, he will sometimes find, especially in the larger drafting rooms, better tools or, perhaps, labor-saving devices. However, we shall explain only the usual standard equipment. You should have most of these although it is possible to do without some of them. The list is as follows:

- This text
- One set of drawing instruments
  - One ruling pen
  - Plain dividers
  - Bow dividers
  - One compass for pencil work
  - One pen for the preceding
  - One bow pencil compass
  - One bow ink compass
- One drawing board
- One T-square
- One triangle, angles 45°, 45°, and 90°
- One triangle, angles 30°, 60°, and 90°
- One irregular curve
- One architect's 12″ triangular scale
- One protractor
- 12 thumb tacks
- One 4H pencil
- One 2H pencil
- One pencil sharpener
- One erasing shield
- One bottle of India ink
- One set of lettering pens
- One penholder
- One penwiper
- One packet of paper containing
  - 15 sheets 9″ × 12″ detail paper
  - 5 sheets 9″ × 12″ vellum (tracing paper)
  - 2 sheets 9″ × 12″ pencil cloth
  - 7 sheets 9″ × 12″ tracing cloth
  - 60 sheets 8½″ × 11″ cross-section paper with light blue squares 1/10″ to ¼″ apart both ways

It is essential that the steel used in the drawing instruments be such that they will wear well. Otherwise the set is likely to cause its owner a great deal of trouble. For example, the threads will wear or perhaps "strip" and the pens will have to be sharpened continually. The best way to be sure that you get a good set is to deal with a responsible maker.

The ruling pen (or right-line pen), Fig *c*, is an instrument for making straight lines in ink It should be about 5″ long The nibs (the ends holding the ink) should appear sharp when viewed along the opening, and pointed but slightly rounded transversely to the opening If the nibs are dull, there is likely to be difficulty in drawing fine lines, if the nibs are too pointed, as seen transversely to the opening, there is often difficulty in

Fig *c*—A ruling pen

Fig *d*—Plain dividers

starting the ink line Usually, new pens are well sharpened It will be found quite convenient to have two pens one for thin lines and one for heavy lines

Dividers are instruments for laying off distances The plain dividers, Fig *d*, have two legs, each about 6″ long The points should be sharp and make a small but perceptible hole in the drawing paper The length of the two legs should be exactly the same, when the dividers are closed, the two points should come together The joint should be tight enough so that the angle between the legs will not change while the instrument is being used; however, it should not be so tight that there is trouble in adjusting to the proper opening

The bow dividers, Fig *e*, are about 4″ long, its two legs are opened and shut by a screw As in the plain dividers, the points should be sharp, the legs of equal lengths, and the points should come together when the legs are closed To avoid wear on the screw thread, it is best when altering the angle between the legs to take the pressure off the thread by compressing the points with the fingers

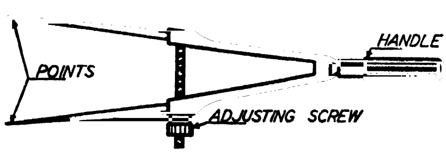


Fig *e*—Bow dividers

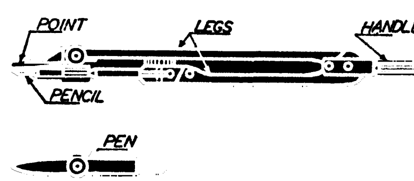


Fig *f*—Compasses

The compasses, Fig. *f*, are instruments for drawing circles. The legs should each be about 6″ long; the lengths must be exactly the same and the points should come together when the compass is closed. In one leg should be a double-ended, removable point; one of these ends is conical, while the other is a "shoulder" point. In the other leg should be either a pen for inking circles or a pencil. The pen, like the ruling pen, should have sharp nibs, rounded in a direction perpendicular to the plane of the legs. The pencil should be removable for renewals; a 4H pencil lead is best.

The bow pencil and the bow ink compass, Fig. *g*, are each about 4″ in length. Like the larger compasses, each has a double-ended point about which each rotates. Like the bow dividers, the points should come together when the legs are closed and it is better to keep the pressure from the screw

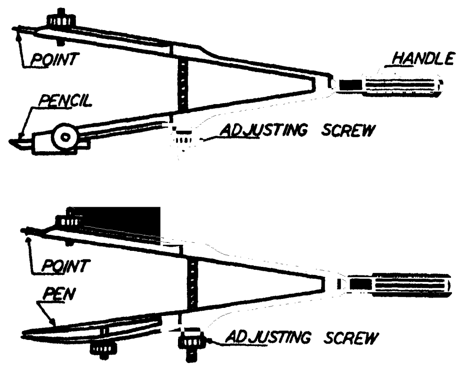


FIG. *g*.—Bow compasses.

thread. Like the larger ink compass, the pen must be well sharpened for good work. The pen for the ink compass and the pencil for the pencil compass cannot be interchanged. These instruments are used for drawing small circles.

The drawing board should be about 6″ larger each way than the largest drawing to be placed upon it, and about ¾″ thick. It should be made of white pine or some other soft wood, carefully kiln-dried. It is important that one of the shorter edges should be exactly straight.

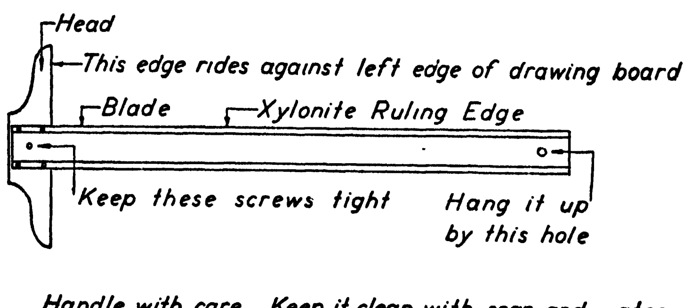


FIG. *h*.—A T-square.

The T-square, Fig. *h*, is used to draw horizontal lines, or as a base on which to rest the triangles so that other lines can be drawn. The long blade should be about the length of the drawing board. The T-square is much more convenient if there are long transparent strips fastened on to both

edges of the blade. The angle between the short blade where it is to rest against the short edge of the drawing board and the upper edge of the long blade should be about 90°. If the connection between the two parts is loose, remedy it by tightening the screws which hold them together.

The size of the triangles to be used depends upon the space available for their storage and the size of the drawings upon which the triangles are used.

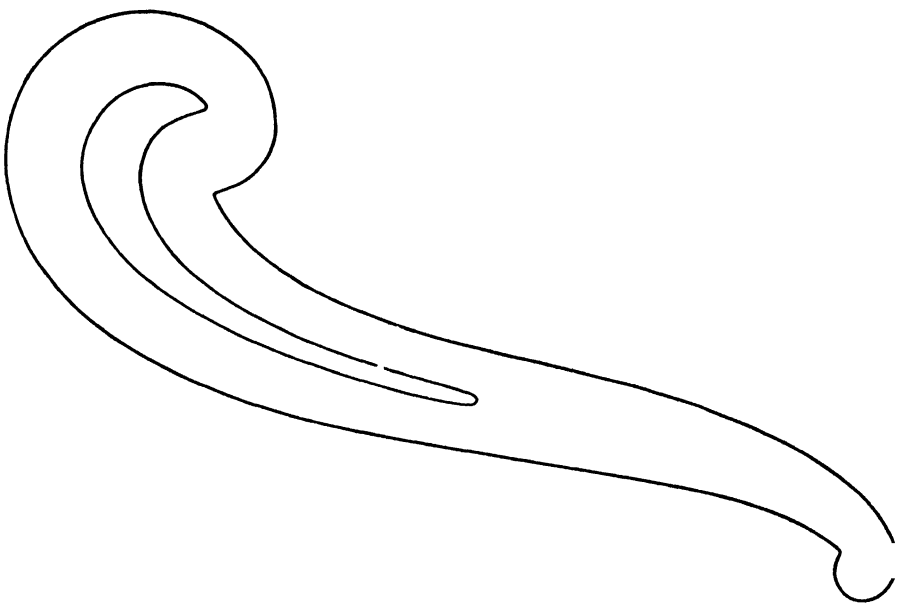


FIG. *i*.—An irregular curve.

The usual length of the larger leg is 8″ to 10″. The common material is celluloid, which has the great advantage of being transparent.

Irregular curves, Fig. *i*, come in various sizes and shapes. The ones to be selected are those most likely to help in the work on hand.

Scales are shown in Figs. 3*a* and 3*b*; the choice depends upon the profession that the draftsman intends to follow. The architect's triangular boxwood scale will meet the needs of this course. The scales given upon this may vary but will be about as follows:

⅛″ = 1′-0″	½″ = 1′-0″	1½″ = 1′-0″
¼″ = 1′-0″	¾″ = 1′-0″	3″ = 1′-0″
⅜″ = 1′-0″	1″ = 1′-0″	12″ = 1′-0″

The protractor should be a semicircle of about 4″ diameter; those made of a transparent material like celluloid are best (Fig. 3*c*). A larger instrument would be more accurate but it is needlessly expensive for this course.

For fastening drawings to the board, a dozen thumb tacks will be necessary. An acceptable substitute is a roll of Scotch tape.

The draftsman needs a hard pencil and one fairly soft; 4H and 2H are usually considered best.

The wood can be removed by a knife or by a pencil sharpener. A sandpaper block may be used to sharpen the lead, but the metal file is more effective.

A hard rubber pencil eraser is a necessity; knives, razor blades, and erasers containing sand must not be used in removing lines from drawings.

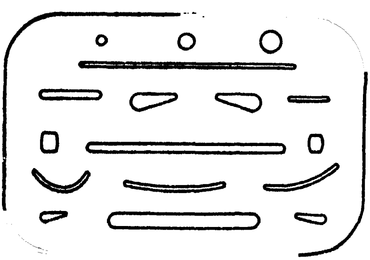


FIG. *j*.—An eraser shield.

The erasing shield, Fig. *j*, a strip of tin or other hard material with a varied assortment of holes, is a great help but it is not a necessity.

For ink use only waterproof India ink of some standard make.

A few lettering pens in the draftsman's assortment should have fine flexible points like the Gillott 303 and 404. In addition there will be needed pens with fine stiff points, and also stiff pens with different sizes of ball points.

The penholder should be suited to the individual needs; it must hold the pen very firmly or good work cannot be done with it.

A small piece of cloth about the size of the hand is required for wiping and cleaning ordinary and ruling pens. The use of a penwiper is essential for a good quality of inking.

All paper listed for use in this course except the vellum should have a firm even texture even after an ink line has been erased from it. A competent draftsman should be able to make a good clean line over a spot where an erasure had been made.

LESSON 1

DRAWING STRAIGHT LINES WITH THE PENCIL

First select one short edge of the drawing board that is exactly straight; if both edges are crooked, one edge of the board should be planed. We will call this exact edge the *working edge*. It should be carefully protected against bumps and needless wear.

Either side of the detail paper may be used. Fasten down the upper left-hand corner (directions are for right-handed persons; in general they are reversed for left-handed people) about 6″ from the top and also 6″ from the left-hand side, the latter being the working edge. Sometimes the drawing is so large that the six inches cannot be obtained and then, of course, we must get along with less.

Now, grasping the T-square by the left hand, make the upper edge of the drawing paper parallel to the blade and tack down the other corner.

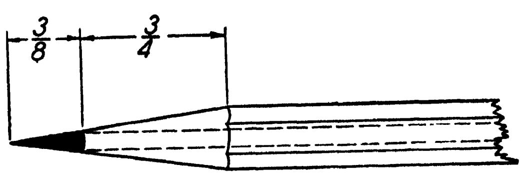


Fig. 1*a*.—A properly sharpened pencil.

The fastening of two corners is enough for ordinary stiff detail paper. If the draftsman prefers, instead of thumb tacks he may use Scotch tape.

Before any work is done with the pencil, it must be sharpened as is shown in Fig. 1*a*. Taper down about ¾ inch of the wood and ⅜ inch of the lead and bring the lead to a fairly sharp conical point. If it is made too sharp, the lead may break or it may cut the paper. If it is too dull, it makes a mark which is too wide and it is hard for the draftsman to see where the point is going.

To draw horizontal lines such as the top cutting and top border lines of the plate:

Set the T-square so a properly held pencil will draw a line in the right place. Hold the pencil vertically except that it is tilted slightly forward as shown in Fig. 1*b*. Then draw the line *from left to right*, holding the T-square firmly with the left hand. If the pencil is gradually turned a little, it will prevent the pointed lead from wearing unevenly.

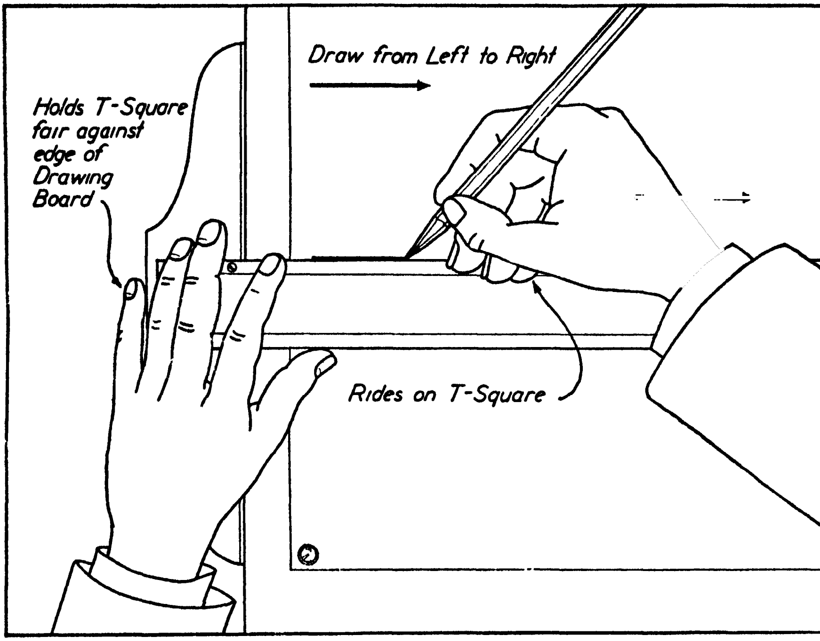


FIG. 1b.—Drawing a horizontal pencil line.

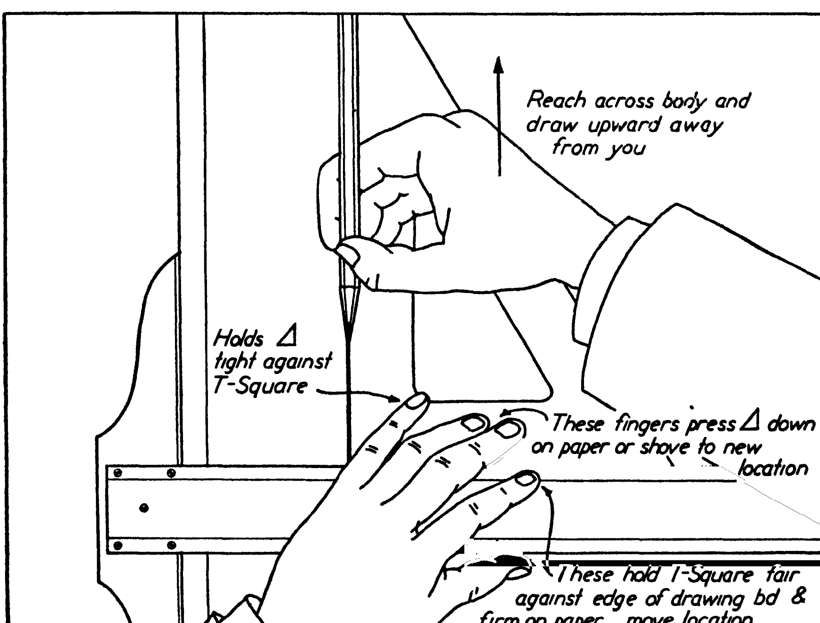


FIG. 1c.—Drawing a vertical pencil line.

To draw a vertical line such as the right-hand cutting or right-hand border line:

Set the T-square against the working edge, holding it firmly with the left hand. Then place upon the upper edge of the blade of the T-square a leg of a triangle. Slide the latter along until it comes to the right position. The acute angle of the triangle should point away from the head of the T-square. Then shift the left hand so as to hold both the T-square and the triangle and draw the well-sharpened pencil from you as is shown in Fig. 1*c*. Keep the pencil in a plane perpendicular to the drawing board but inclined a little forward. Be careful to keep successive positions of the pencil parallel as you draw a line; otherwise the line will be crooked.

To draw an inclined line, set the triangle in position and draw from left to right.

When it is not known how long a line will be, draw it very lightly at first and then make it a clear sharp black line by going over it again after its limits are determined. If one knows these limits, the line should be clear and black the first time it is drawn.

SKETCHING

Views are made in two ways:

When made by accurate instruments with distances equal to those on the object or proportional to them and the angles exact size, it is called a *drawing*.

When lines are drawn free hand with angles and distances estimated, it is termed a *sketch*.

Often drawings are made with parts that are not to scale, and some sketches are drawn very carefully, using straight edges. Such may be termed intermediate between drawings and sketches. It is best to learn to do real sketching; it is easy to adapt yourself to various aids. Hence all work in sketches is to be done entirely free hand.

In general, the same kinds of views can be drawn by both methods. Sketching is more common for the simpler jobs, for less complicated objects, and for emergency work.

The pencil used should be a well-sharpened 2H pencil, just soft enough to make a clear black line. The paper should be $8\frac{1}{2}'' \times 11''$, marked with light blue squares, about $\frac{3}{16}''$ on a side.

In making a sketch, it is well at the beginning to decide upon some approximate scale, say, 4 squares to the inch. This scale is followed as closely as possible without taking too much time, estimating distances where necessary. When you are uncertain how far a line will go, make it light at the start and darken it afterward; but when its length and position are known, draw it with the proper weight the first time that the line

is made. Care should be taken that the lines of the object are really black so that they stand out clearly in contrast to the center lines, the dimension lines, and the extension lines, which are made very light so that they will not be confused with object lines.

It is important in sketching that you should be able to see clearly the relative position of points and lines and then transfer this relation to your sketch. If a line is curved it should be shown as such, and the length of the radius of curvature should have the same relation to the other parts in the original and in the sketch.

LETTERING

The following points are of the utmost importance. Keep them clearly in mind without taking too much time:

Clearness.—Above all else, either in a memorandum, a sketch or a drawing, the letters must be so plain that they cannot possibly be mistaken.

Form.—Study carefully the shape of the letters given in this text and copy them as closely as you can.

Slant.—The slant of the letters must be kept alike in a drawing or a sketch. The letters in your first set are vertical and must be vertical in your work. The letters in the latter set are inclined 20° from the vertical, and all lines that are vertical in the vertical lettering must be kept at this slant of 20°.

Height.—Letters are usually from $\frac{3}{32}''$ to $\frac{1}{4}''$ high, varying with their importance. Ordinary lettering should be about $\frac{1}{8}''$ high. If there are one or more lines of lettering, use light pencil lines (guide lines) to keep the height uniform.

Spacing.—Letters should be so placed with reference to each other that they appear to be equally spaced. It will be found that the actual distances between them are not quite the same. In Lesson 14 is a table giving numerical values for the width and the spacing of letters with rules for their application.

Execution.—Practice until your letters are uniform in height and weight of line. The nervousness, the shakiness, and the inability to control small motions of the pencil will gradually disappear.

REQUIRED WORK: LESSON 1

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

Questions

1-1. Explain the difference between the orthographic and the perspective view.
1-2. How is a blue print made?
1-3. What are six important points in making letters?
1-4. State how a vertical line is drawn.

SHEET 1-1 (Fig. 1*e*)

1-5. How wide is Main St.? (The distance follows the name of the street.)
1-6. Which lot do you prefer and why?

SHEET 1-2 (Fig. 1*h*)

1-7. What is the span (how long) of the roof truss?
1-8. What is the greatest height of the bridge?

SHEET 1-3 (Fig. 1*i*)

1-9. Could we have another row of tennis courts if we removed the track and football stands?
1-10. The distance base to base is 90 feet. How many feet to the inch in the cut?
1-11. How many yards are allowed for overrunning in the 100-yard track?

SHEET 1-4 (Fig. 1*j*)

1-12. Determine the number of enlisted men in this camp if there are eight to a tent.
1-13. Count the number of wash rooms.

SHEET 1-5 (Fig. 1*k*)

1-14. How many points are there?
1-15. What is the greatest number of lines which meet at one point?
1-16. How many lines are there?

Sketches

1-17. Sketch the perspective of some building with which you are familiar.
1-18. Draw free hand the layout of Fig. 1*e*.
1-19. Sketch a bow compass for inking circles.
1-20. Illustrate the correct position of the hands when drawing horizontal lines.

LETTERING (Fig. 1d)

Make these letters, both the vertical and the inclined, first $\frac{1}{4}''$ high, then $\frac{3}{16}''$ high, and finally $\frac{1}{8}''$ high. Do not put them on your finished sheets until you have practiced enough so that you can do a good job.

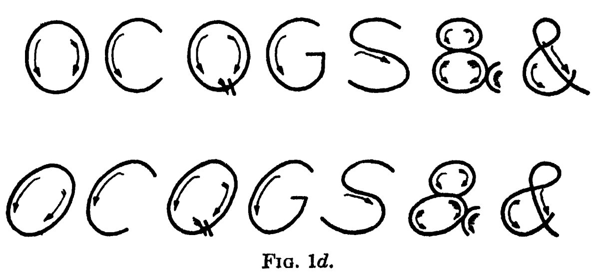


FIG. 1*d*.

The directions of the strokes are indicated by the arrows. The order is shown by the number of strokes on the tail of the arrow. The last character represents "and so forth."

SHEETS

There are shown in this lesson Sheets 1-1, 1-2, 1-3, 1-4, and 1-5. Go over all of these quite carefully until you understand how each is done. Select one of these and make it just twice as large; it is to be in pencil upon detail paper.

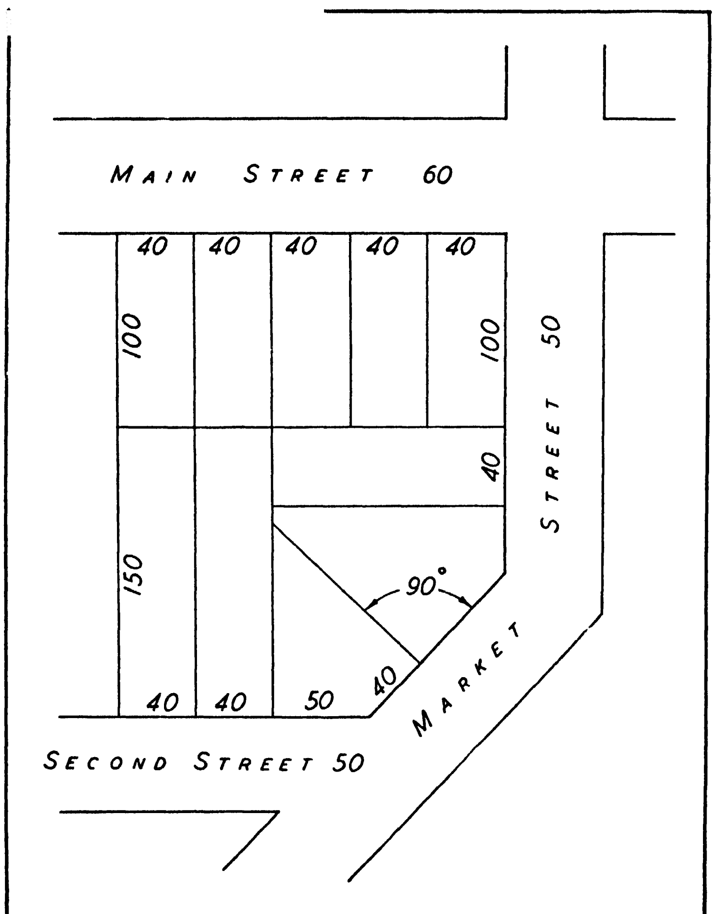


FIG. 1c.—A plan of lots.

The angles will remain unchanged by this enlargement. The distances must all be doubled. This can be done quickly by setting your dividers to the distance in the cut and then making the corresponding distance in your drawing equal to two spacings of the dividers. In making the measurement, rotate the dividers by the handle, taking care not to touch the legs after the instrument is set.

Copy the lettering carefully. If it is changed at all, be sure that it is an improvement.

Possibly you can make a better layout of the camp, the lot plan, or the athletic field, but do not attempt any changes unless they are approved by your instructor.

Use a 2H pencil for your lettering and a 4H for your lines.

Sheet 1-1 (Fig. 1*e*)

This lot plan, Fig. 1*e*, consists largely of horizontal and vertical lines. Part of Market St. is oblique, its direction being determined by the ends

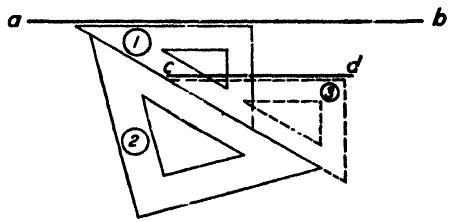


Fig. 1*f*.—Method of drawing two parallel lines with two triangles.

of lines that are horizontal or vertical. To draw a line parallel to an oblique line, proceed as illustrated in Fig. 1*f*. Set two triangles as shown, one of the legs of the 30-60° triangle in position (1) being parallel to *ab*. Then triangle (2) being held firmly in position, move the 30-60° triangle to position (3) and draw the line *cd* which is parallel to *ab*. There are several other ways in which this may be done.

To draw a perpendicular to an oblique line, Fig. 1*g*:

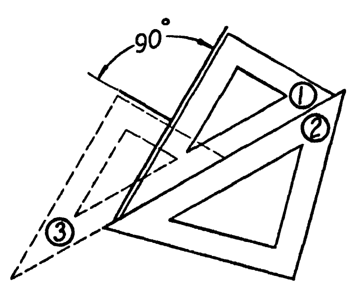


Fig. 1*g*.—Method of drawing one line perpendicular to another with two triangles.

Set two triangles as shown, one of the legs of the 30-60° triangle in position (1) being parallel to the oblique line. Then, triangle (2) being held firmly in position, move the 30-60° triangle to position (3). There are several other combinations of triangles with which the perpendicular may be constructed.

Sheet 1-2 (Fig. 1*h*)

In the roof truss, the spaces on the top are equal. The bridge truss has equal spaces on the bottom. In each case the portion that carries the load is equally divided.

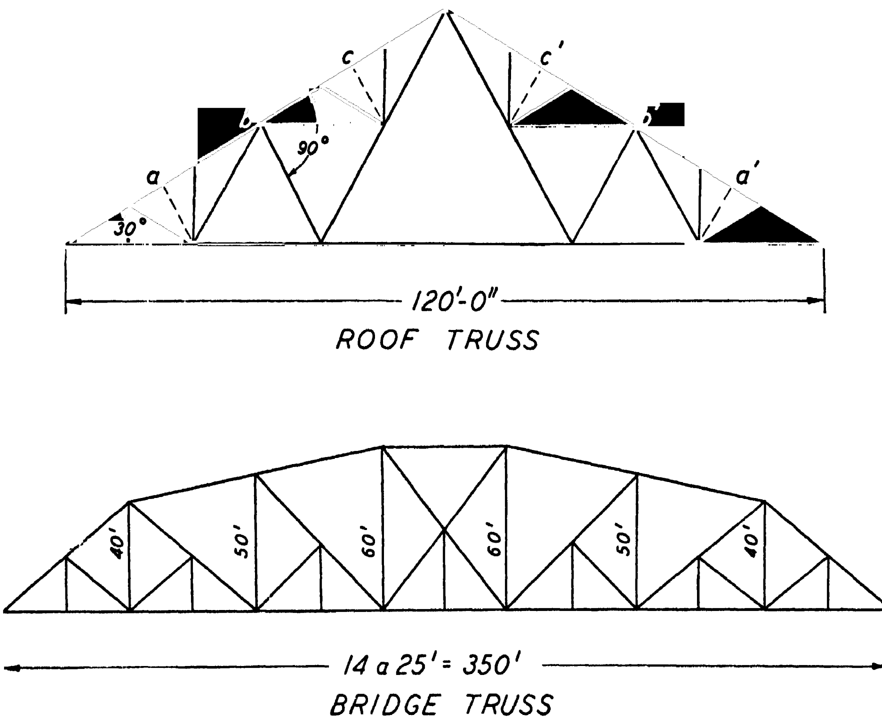


Fig. 1*h*.

Sheet 1-3 (Fig. 1*i*)

Here is shown a typical athletic field with tennis courts in the upper portion and a hundred-yard track nearby. In the lower part is a baseball diamond which uses a portion of the football gridiron as its playing field. Stands are provided for baseball and football.

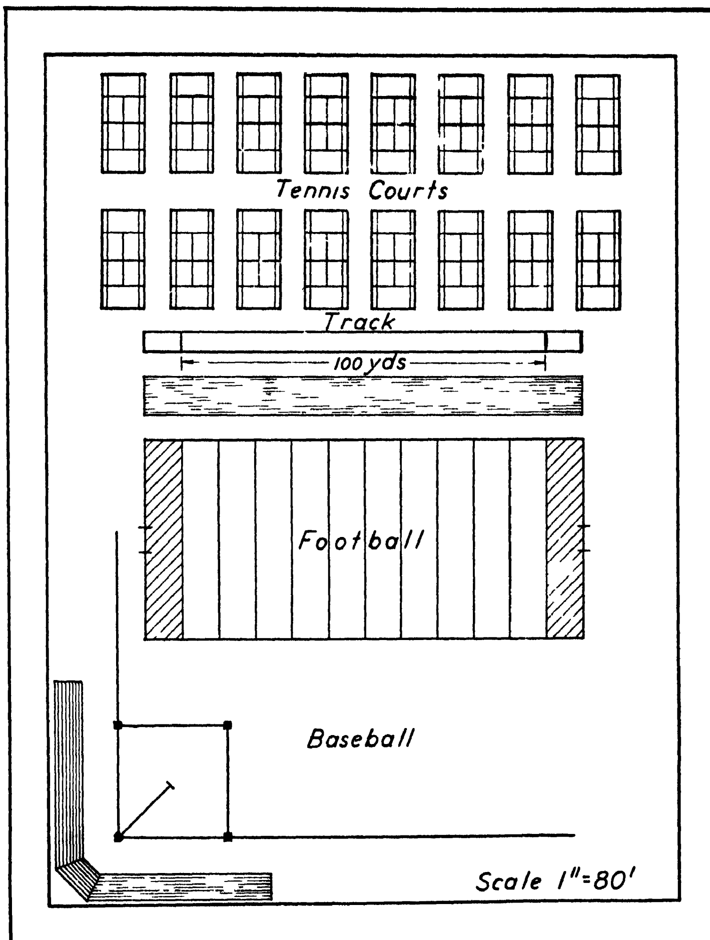


Fig. 1*i*.—An athletic field.

Sheet 1-4 (Fig. 1j)

Here there is shown a typical camp for about 1400 men.

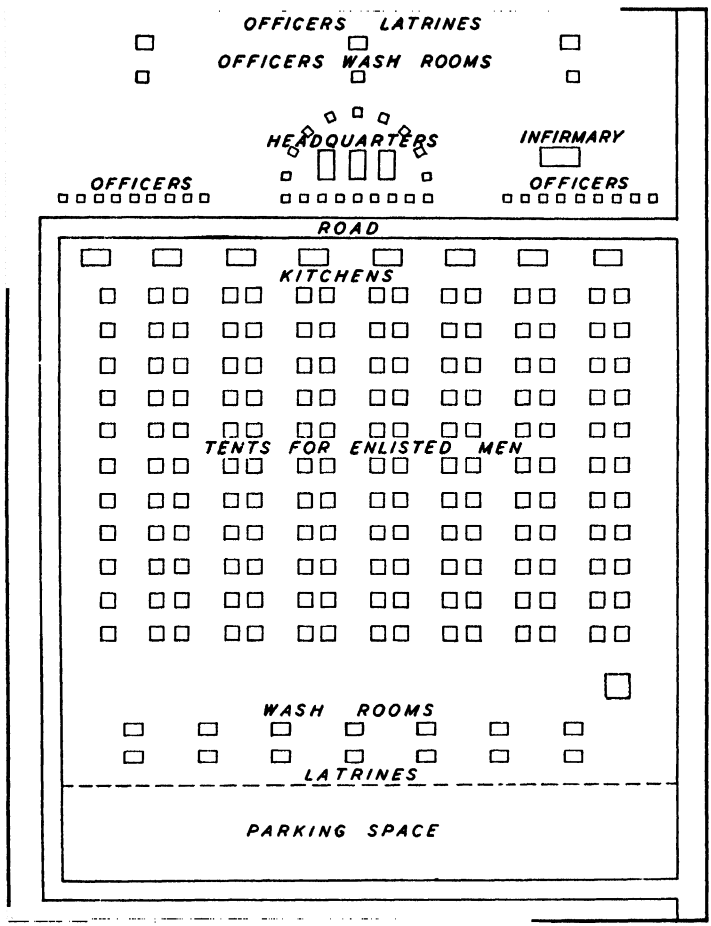


Fig. 1j.—An army camp.

SHEET 1-5 (Fig. 1*k*)

This is a plot of points in a triangulation survey. The two bases are measured, angles are taken at all points, and then all distances are computed.

We have now reached the end of your first lesson. Be sure that the work you have turned in is the best of which you are capable.

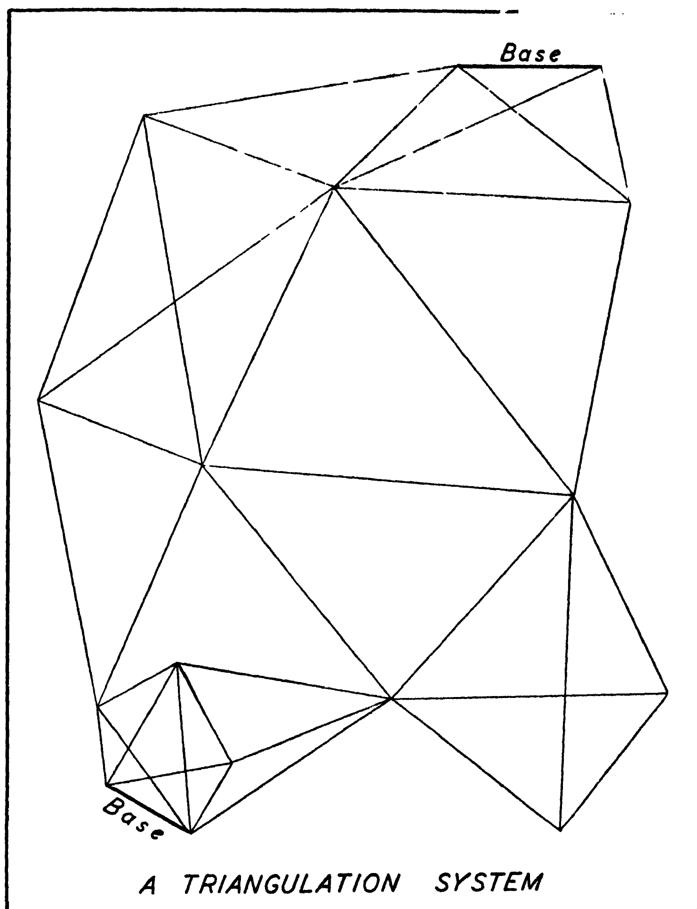


FIG. 1*k*.

LESSON 2

DRAWING CURVED LINES WITH THE PENCIL

DRAWING CIRCLES IN PENCIL

First place the needle at one end of one leg of the compass so that the "shoulder" point is out. Next, in the other leg place a hard (4H) lead. This is to be sharpened to a chisel point so turned that it will lie in the circumference of the circle that is to be drawn. Finally, adjust the length of

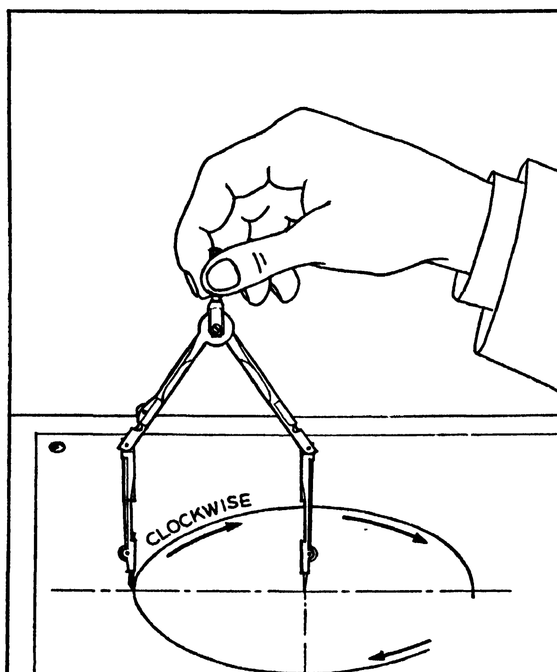


Fig. 2a.—Drawing a circle.

these two so that the chisel point comes halfway in length between the point of the needle and its shoulder.

To set the compass to a given radius:

First lay off the required distance on paper, preferably where the circle is to be drawn, and then set the compass to this measurement. It is best to

test it by making an arc and measuring the radius so obtained; if it does not agree with that required, then the compass must be reset.

To draw a circle, Fig. 2*a*, first set the legs the proper distance apart, keeping the handle and the needle point perpendicular to the plane of the paper. Then rotate it by the handle in a clockwise direction. The compass is inclined slightly forward as is shown in the cut. After the compass is set, the fingers should not come in contact with the legs.

Bow compasses are preferred where they are large enough; when they are too small, the plain compasses must be used. The former are more easily adjusted and there is less likelihood of their radius being accidentally shifted.

Arcs and circles should be drawn before any straight lines with which they connect. Usually, much care is exercised to make the circles accurate; then the connecting lines are made to match. It is much easier to connect a straight line to a circle than it is to make an arc to fit a line.

Small circles are sometimes drawn free hand. However, the best practice is to do this only for circles too small to be drawn by ordinary compasses.

IRREGULAR CURVES

Suppose that we have a series of points through which a line must be drawn. The treatment varies according to the conditions:

If the points are located on a line of nature—a creek, a shore line of the ocean, the surface of the ground, or something similar—we call it a *natural* curve, and it is drawn free hand.

If the points are on an artificial line—for example, a wall, an edge of a casting, or one side of a winding highway—we call it an *artificial* curve, and it is drawn by instruments. It is customary to represent laws and rules (for example, see Fig. 2*m*) as artificial curves.

DRAWING IRREGULAR NATURAL CURVES WITH THE PENCIL

Draw firmly and steadily but free hand a clear black line through the points in question as shown in Fig. 2*b*. Be careful to turn the line steadily, avoiding all appearance of sharp angles.

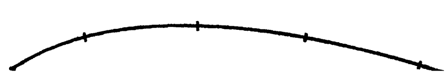


FIG. 2*b*.—Drawing an irregular curve.

DRAWING IRREGULAR ARTIFICIAL CURVES WITH THE PENCIL

The first step is to draw the line free hand in pencil as for natural curves, except that the line must be very light. Then fit the irregular curve (the instrument) to the free hand line. Do not draw the line for the full

length that the curve fits but stop an eighth of an inch short at either end. If the connecting line on either side is already drawn, make the curve (the instrument) fit it for at least ⅛ inch. Be certain that the curve is tangent where it should be and that there are no sudden changes of direction unless they are on the object that you are drawing.

Sometimes a circular arc can be used to advantage as a part of an irregular curve, as in the portion of the ellipse shown in Fig. 2c. In this

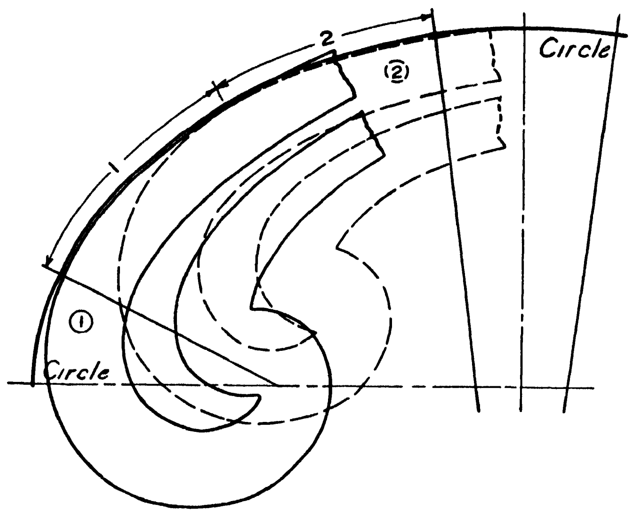


FIG. 2c.—Drawing an ellipse.

case, on account of the symmetry of the ellipse, the small circle as well as the large circle can be used, each in another place. The irregular curve, position (1), may be used again; and, by turning over the same length may be employed twice more. Similarly, the irregular curve, position (2), may be used four times in all.

LETTERING

The operation of making these letters calls for the characteristics already indicated in the preceding lesson.

Letters and words must be such that their meaning is very clear. Use abbreviations and symbols only when you are certain that there will be no possibility of misunderstanding their meaning.

The forms of letters are important. When you are making a letter for the first time, study the form shown in the text very thoroughly and then copy it as carefully as you can. For example, the angle at the top of the A on the normal letter should be 53° and the horizontal bar should be one-third the way up. For letters that are spread out, the angle may be

increased; for letters that are compressed, it may be decreased. However, if the angle or the height of the bar is materially changed except for apparent causes and similar changes elsewhere, it will hurt the appearance of your lettering. A table giving the numerical proportions of letters is in Lesson 14.

The crowding together of letters to form words and sentences makes a uniform slant absolutely necessary. The best way to do this for inclined lettering is to draw very light lines of the proper slope (about 20° from the vertical) across the part to be lettered. Similar reasons make height important; light pencil guide lines are used by most good draftsmen.

Practice is required for good lettering. The greatest efficiency is obtained by periods of about half an hour. Try to do your lettering only when your mind is capable of continual effort to improve.

ERASURES

Mistakes must be corrected by removing the erroneous material. Often when there are no errors, changes are made necessary by alterations in design.

A hard ruby eraser is best for pencil and ink lines. (Soft erasers and art gum are well adapted for cleaning a drawing.) Paper, especially the thinner kinds, must be firmly held while the draftsman is rubbing. To prevent the erasure of portions that are correct, it is best to use the eraser shield, selecting the most suitable opening. Sometimes a piece of paper is held firmly over the part which is not to be changed.

Try a new rubber on a scrap of paper. If it leaves a discoloration, cut off the surface of the eraser and try again. If it does not now leave a clean surface, get a new eraser.

REQUIRED WORK: LESSON 2

Answer eight questions, make two sketches, do the lettering and draw one sheet.

2-1. Explain the method of setting the legs of a compass to the desired radius.
2-2. What is the difference between a natural curve and an artificial curve?
2-3. Describe the method of making erasures upon a pencil drawing.
2-4. In which direction should a compass be rotated?

SHEET 2-1. DISTANCE DIAGRAM (Fig. 2*e*)

2-5. In a right triangle, one leg is 3″ and the other is 5″. What is the hypotenuse?

2-6. The acute angles of a right triangle are 15 and 75 degrees, and the hypotenuse is 4″. What are the lengths of the two legs?

2-7. The large leg of a right-angle triangle is 10″, and the acute angles are 30 and 60 degrees. What is the length of the other leg and the hypotenuse?

Hint: Divide the length by two, solve by the diagram, and then multiply the answer by two.

SHEET 2-2. A PUMP HANDLE (Fig. 2*g*)

2-8. How many holes are there in this piece?
2-9. What is the greatest width of the pump handle perpendicular to its axis?

SHEET 2-3. A PARK (Fig. 2*h*)

2-10. How many tangents (straight lengths of streets) are there in Paradise Drive?
2-11. Determine the number of sides in the flower bed.
2-12. What is the shape of the space allotted to the shrubs?

SHEET 2-4. CONTOURS (see instructions for drawing, Fig. 2*l*)

2-13. What are the dimensions of the area shown?
2-14. About what will be the highest elevation in the tract?

SHEET 2-5. A DISCHARGE DIAGRAM (Fig. 2*m*)

2-15. How much water will be discharged by a 10″ pipe running full on a grade of 4 feet per hundred?

2-16. What size of pipe running full will be required to carry two cubic feet per second on a grade of 3 feet per hundred?

SKETCHES

2-17. Sketch the pump handle

2-18. Sketch Paradise Drive, Sheet 2-3, and revise the arrangement of the flowers and shrubs to suit your own ideas.

2-19. Sketch the correct position for drawing a circle with a bow compass.

2-20. Take a sheet of transparent paper and copy sheet 2-4. Then by trial run a line from the lower left-hand corner to the upper right-hand corner, using equal distances from each contour to the one below. The work may be done most conveniently with bow dividers. Make the last step at the upper right-hand corner a half space. Then sketch in this line. It would be the center line of a highway on the surface of the ground that would have a uniform grade.

LETTERING (Fig. 2d)

In this lesson we take up letters that are partly of curved lines. These portions are parts of ellipses and should be drawn as such.

Sequences and directions of stroke are indicated as in Lesson 1.

Letter, like Fig. 2*d*, all the letters shown therein, both vertical and inclined, first ¼″ high, then $\frac{3}{16}$″ high, and finally ⅛″ high.

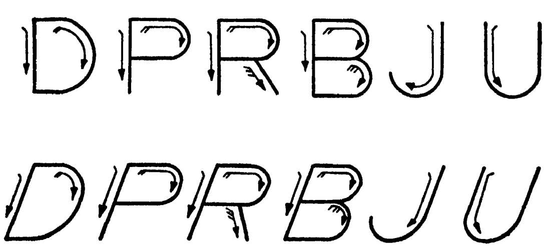


FIG. 2*d*.

SHEETS

Here again all sheets are to be studied, but only one plate out of five is to be selected and drawn. Copy this but make it just twice as large. All work is to be in pencil on detail paper. Use a 2H pencil for your lettering and a 4H for your lines.

Sheet 2-1. A Distance Diagram (Fig. 2*e*)

This should be laid off directly by the student rather than copied. Place a 5″ × 8″ rectangle in the middle of your working space and divide

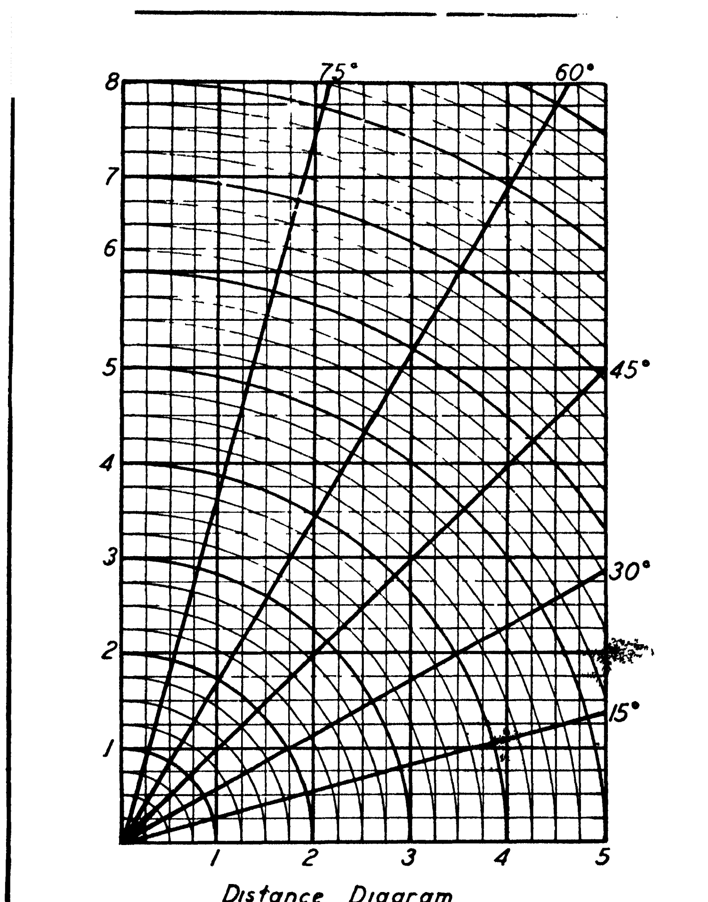


Fig. 2*e*.

very carefully as shown. The angles 30°, 45°, and 60° may be drawn by one of your regular triangles. The angles 15° and 75° may be laid off by your

two triangles in combination, if we recollect that 45° + 30° = 75° and 45° − 30° = 15°. Figure 2*f* shows how angles of 15° and 75° from the

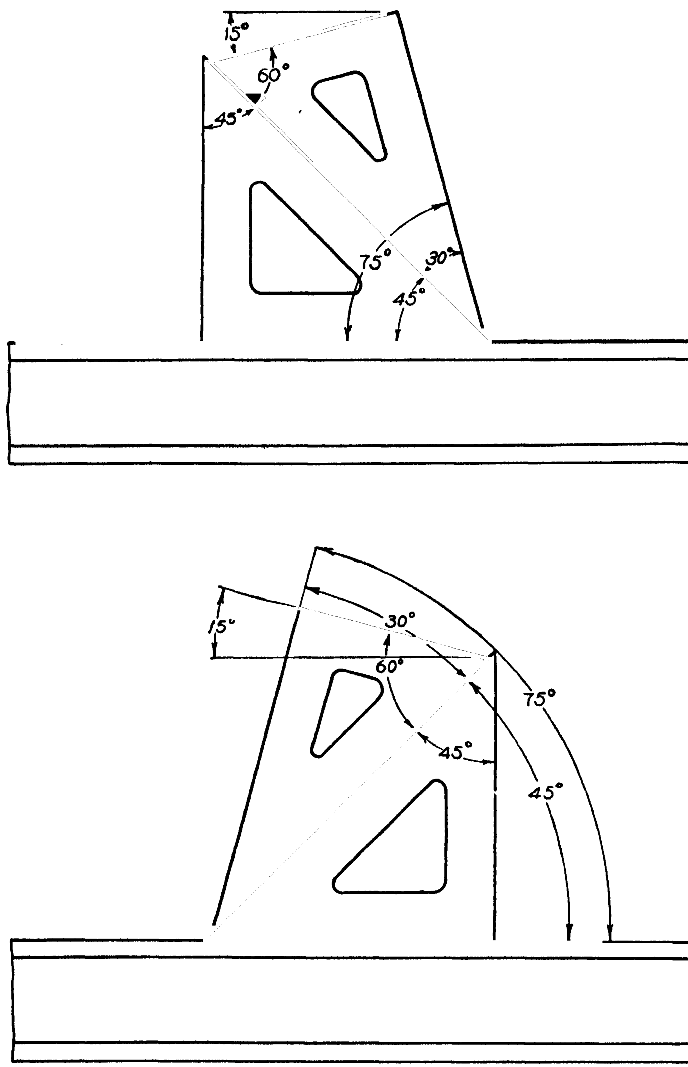


Fig. 2*f*.

horizontal may be obtained. Other combinations can be arranged to give the same result.

Extreme accuracy is required to make this diagram of practical value.

Sheet 2-2. A Pump Handle (Fig. 2*g*)

In the cut in your text, divide the inclined dot and dash line into short intervals. Then copy the center lines and the intervals on your sheet, making all lengths twice as great on your drawing, and erect perpendiculars at each division point. Then locate on the cut enough points on the pump handle to determine accurately its shape. Place these same points upon your drawing, making the distances from the inclined center line and its perpendiculars twice the same values on the cut. Be very careful to get smooth curves throughout the drawing. Where there is a circle or an arc

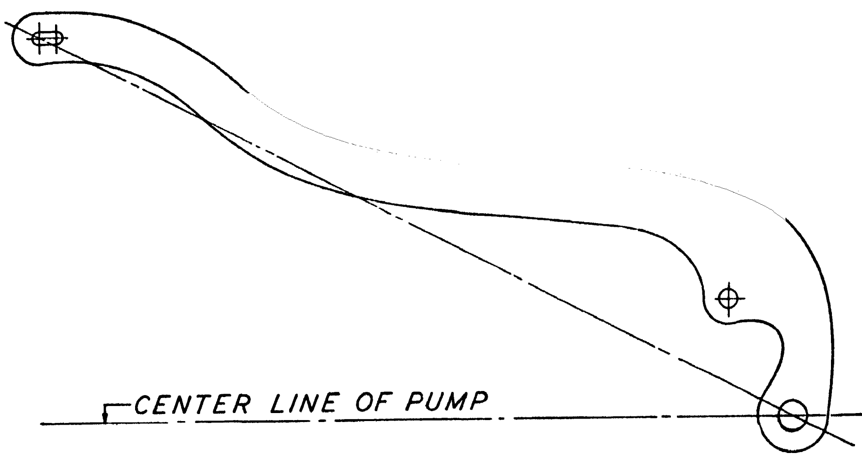


Fig. 2*g*.—A pump handle.

of a circle, locate its center as indicated above and draw the arc with twice the radius in the cut. In general, circles should be drawn first.

Sheet 2-3. A Park (Fig. 2*h*)

Draw a horizontal line and a vertical line through the center of the cut, and then do the same in the working space in your sheet. Then in the cut select the important points and drop perpendiculars to the center lines just made. Draw the corresponding perpendiculars upon your sheet, but make all measurements twice as great; their intersection will determine the selected important points. Locate first the centers of the curves; then draw the curves, using, of course, double radii, and finally connect these curves as shown in the text.

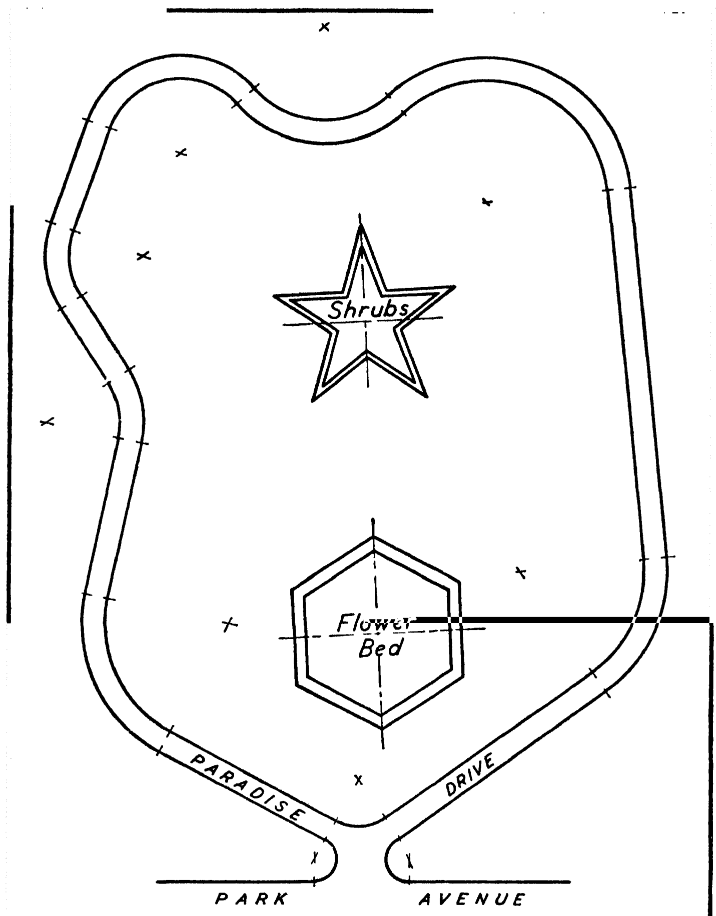


FIG. 2h.—A park.

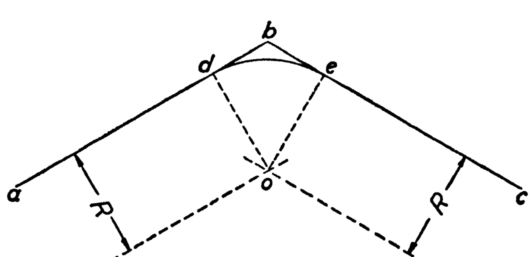


FIG. 2i.—Construction of a curve between two lines.

Suppose in Fig. 2*i*, it is required to connect two intersecting lines *abc* by a curve of radius *R*. Draw parallel to *ab* a line distant *R* from *ab*, and similarly a line distant *R* from *bc*. Their intersection at *o* is the center of

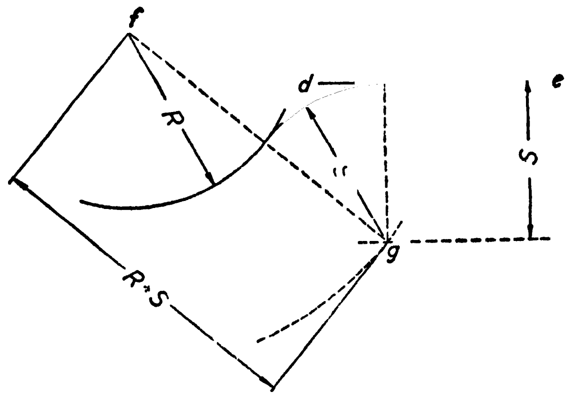


FIG. 2*j*.—Construction of a curve between a line and a curve.

the required curve. The lines *od* and *oe*, perpendicular, respectively, to *ab* and *bc*, determine the length of the curve. Usually *bd* and *de* are erased upon the finished drawing.

In Fig. 2*j* let it be required to connect the curve of radius *R* and the straight line *de* by a curve of radius *S*. It is clear that the center of the new curve will be distant $R + S$ from *f*. It is also plain that the center sought will be on a line distant *S* from *de*. Hence from *g* where the new line intersects the new curve we draw a curve with radius *S*. Connect *fg* and drop a perpendicular from *g* to *de* to determine the limits of the curve of radius *S*. The projecting line and the projecting curve are usually removed from the finished drawing.

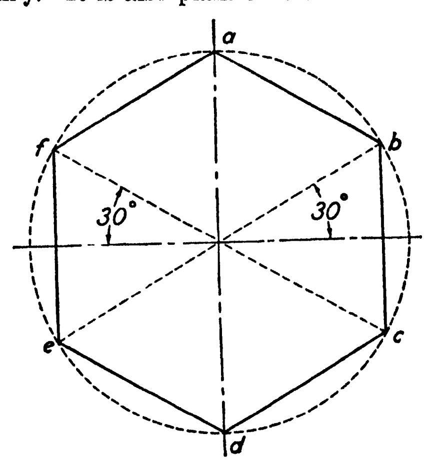


FIG. 2*k*.—Construction of a hexagon.

The center of the five-pointed star may be determined, as for other centers, the circle drawn that includes its points and one star point located. Then divide the circle by trial into five equal parts, using your dividers. Finally connect the first point with the third, the second with the fourth, and so on, and erase the center part of the lines. The inside lines may then be drawn, using the method explained for Sheet 1-1.

The six-pointed flower bed can be drawn in a somewhat similar manner. It is quicker, however, after having located the center, drawn the circle and determined the top point, to proceed as shown in Fig. 2*k*. Here two 30° lines determine everything. Note that *bc* and *ef* are vertical and *ab, af, cd,* and *de* are inclined 30° to the horizontal.

Sheet 2-4. Contours (Fig. 2*l*)

This field is laid out in 100-foot squares which should be 1″ apart on your sheet. Lay these squares out first. Then draw the irregular lines

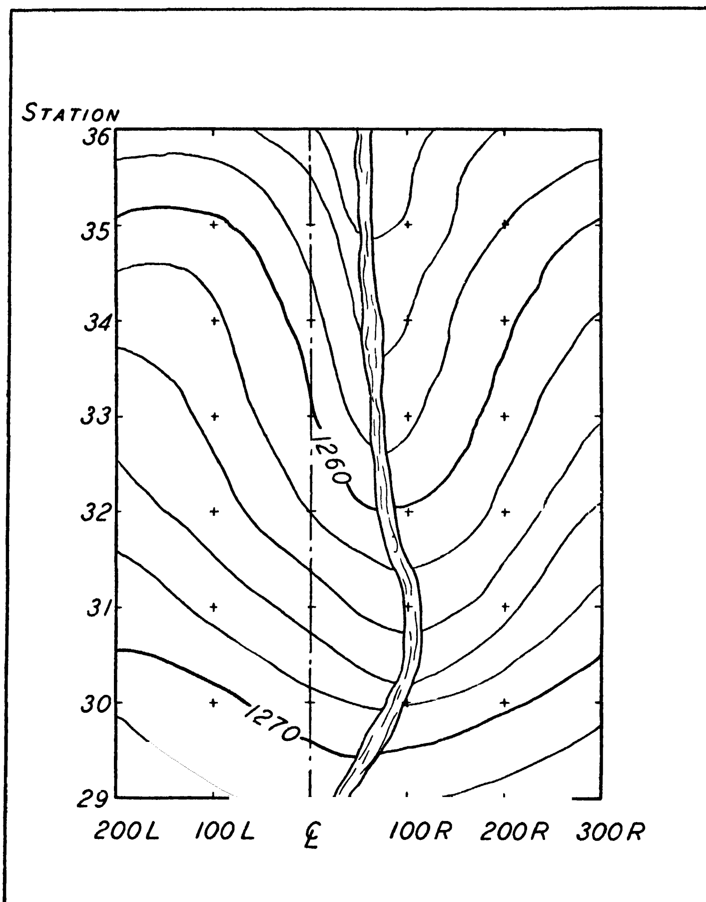


Fig. 2*l*.—A survey with contours.

from their intercepts (points where the irregular lines cross the squares). Be careful to sketch them between these intercepts as much like the cut as possible.

About in the middle is a creek. The other irregular lines are lines of equal elevation. For example, every point in the line marked 1260 is 1260 feet above some point, probably sea level. Every fifth line is heavier and is numbered.

Lines of equal elevation are called contours.

SHEET 2-5. A DISCHARGE DIAGRAM (Fig. 2*m*)

Proceed here as in the preceding sheet, but use an irregular curve to draw the curved lines. Ask your instructor if you do not see how this diagram works.

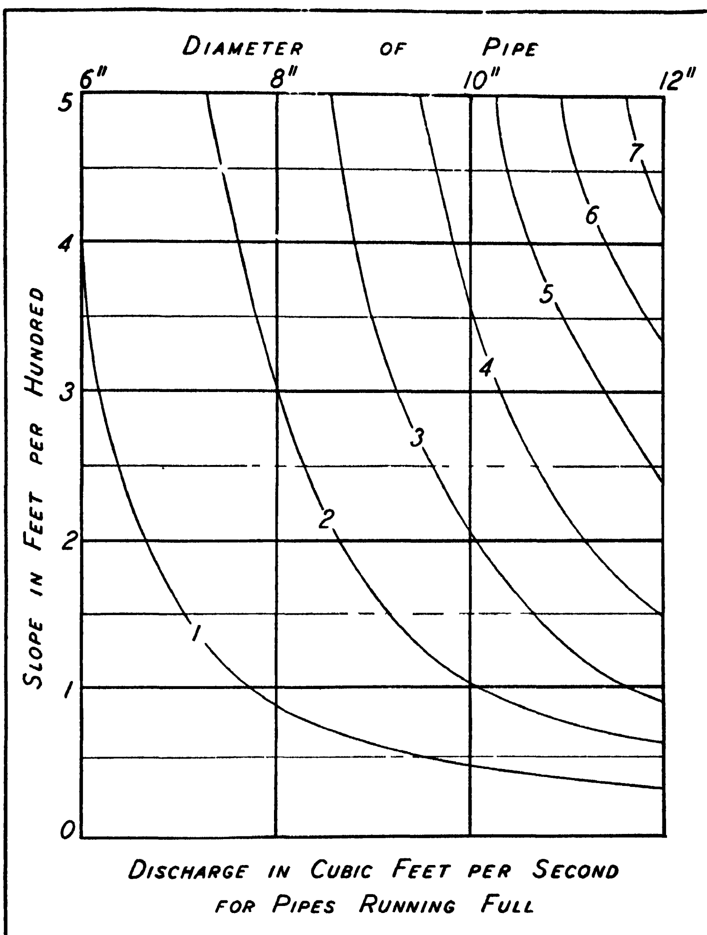


FIG. 2*m*.

LESSON 3

VIEWS. SURVEYING. SCALE PROTRACTOR

The purpose of drawing is to describe an object in such a way that a person trained in the art can understand exactly what is meant. For example, if a man decides to build a home, he first has an architect prepare views of the proposed dwelling place. These views are so chosen that they completely describe the house. They are used by everybody. The family go over them to be sure that they represent what they want. All contractors use them to prepare their bids; the successful contractor builds the house from them under the supervision of an inspector who verifies the agreement of the building with the drawing. For all these uses, the views must be clear, complete, and accurate.

These views are practically what one would get with a camera pointed squarely at the object. They are changed, however, very slightly, so that each measurement is exactly the same as that on the object; or very often in practice, distances are reduced while angles are unchanged, leaving drawings much like the object but smaller.

An orthographic drawing is one in which the distortion, seen when viewed by the eye, is entirely removed. It is a view in which the eye is supposed to be directly opposite every point represented on the drawing. It may also be defined as the outline obtained when perpendiculars are dropped to an imaginary plane, this plane being usually located parallel to an axis or face of an object.

In some cases, only one view of an object is needed; thus the plan of lots in Fig. 1*e* may be regarded as a view taken from an airplane overhead. Sometimes a single view will do in connection with a note; for example, Fig. 2*g* would fully specify the pump handle if the thickness were given and also the scale of the drawing. Again the information is implied rather than expressed; for instance, in Sheet 3-1, the object that is marked a shaft is known to be round; hence no other view is needed. Perhaps the most frequent use of the single view is in surveying.

Surveying is done by measuring horizontal distances and by taking angles with a transit that records the angles in a horizontal plane. It follows then that these distances and angles are exactly what we would see if we were directly above and looked down on that particular portion of the earth.

Now to make a drawing corresponding to the survey (usually called a plan), we measure the distances on the paper with a scale and the angles

that were turned off with the transit we lay off with the protractor. That is, the plan shows the same angles as the survey, and the distances, too, are the same or all reduced in the same proportion.

It is usually necessary to make the drawing smaller than the land that it represents. Often 1 inch on the drawing is made to represent 50 feet on the ground; this of course is a reduction of 600 to 1. It would be awkward and likely to lead to mistakes if we had to divide each distance by 600 before laying it off with a rule. Instead, we have a much easier way; we have scales that make the reduction for us.

The common type used in surveying is the decimal scale made in a triangular form of boxwood. This is shown in Fig 3a. There are six edges

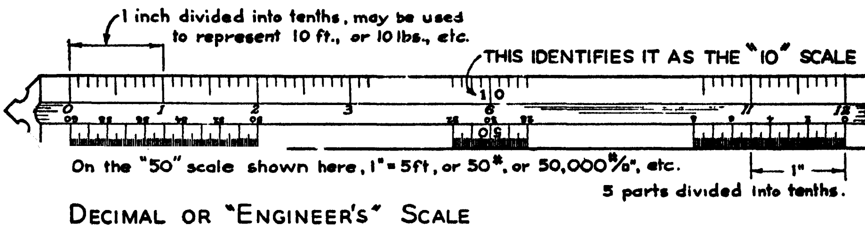


FIG. 3a.

on a scale of this kind; on each edge there are measurements that give a certain reduction ratio. A common arrangement is to have the following reductions:

1″ = 10′-0″	a reduction of 120 to one.
1″ = 20′-0″	240 to one.
1″ = 30′-0″	360 to one.
1″ = 40′-0″	480 to one.
1″ = 50′-0″	600 to one.
1″ = 60′-0″	720 to one.

On the two edges visible in the cut, the scales are 1″ = 10′-0″ and 1″ = 50′-0″. As will be evident from its use and from the notation on the cut, the first may likewise be used for 1″ = 1′-0″ and 1″ = 100′-0″; the second for 1″ = 5′-0″ and 1″ = 500′-0″.

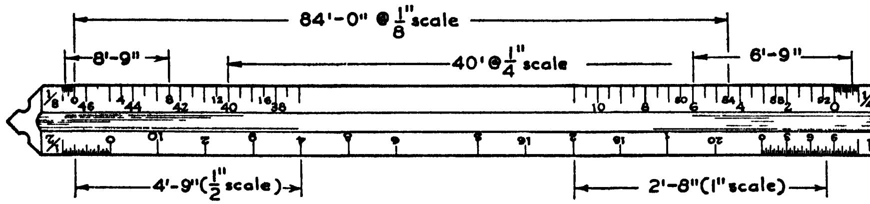
Let us examine more carefully the scale for 1″ = 50′-0″. Here we will find that each inch is divided into 50 parts; hence, at 1 inch to 50 feet, each small part represents 1 foot. Usually every fifth division is made longer, every tenth one longer still, and every twentieth one is numbered.

Let us suppose that 64 feet is to be measured at a scale of an inch to 50 feet. We first set 0 on the scale at the starting point, then count off 64 little divisions along the scale. We are helped by the fact that it is just four little divisions beyond the large division marked 6. That is, the interval from 0 to 4 little divisions beyond the 6 on the side marked 50 represents 64 feet at a scale of 1″ = 50′-0″.

The scale that we have just used is the decimal scale. Figure 3*b* shows the architect's scale. Here we have usually the following reductions:

⅛″ = 1′-0″	a reduction of	96 to one.	
¼″ = 1′-0″		48 to one.	
½″ = 1′-0″		24 to one.	
1″ = 1′-0″		12 to one.	
3/32″ = 1′-0″		128 to one.	
3/16″ = 1′-0″		64 to one.	
⅜″ = 1′-0″		32 to one.	
¾″ = 1′-0″		16 to one.	
1½″ = 1′-0″		8 to one.	One eighth scale
3″ = 1′-0″		4 to one.	One quarter scale
12″ = 1′-0″		1 to one.	Full size.

Half size is used quite a bit and it is sometimes placed upon the scale. Note particularly that the first ten are arranged two to an edge, one



COMMON OR "ARCHITECT'S" SCALE

FIG. 3*b*.

reading from each end. At either end we have a foot (at the reduced size) divided to represent inches.

Let us consider the scale which represents ½″ = 1′-0″ or one-twenty-fourth size. At the end to the left of 0 is a foot divided into twelve parts representing 1 inch, or, as in the cut, into twenty-four parts each ½″. To the right of the 0, marks are placed ½″ apart, each representing a foot with every second foot numbered. Thus to measure 4′-9″, set 9″ on the subdivided foot at the point of beginning; then the end will come at the line marked 4, all as shown in the cut. A beginner may prevent mistakes by also measuring the proper distances in inches; for example, 4′-9″ at ½″ to the foot is 4¾ divided by 2 = 2⅜″.

In measuring distances use a pencil well sharpened to a conical point. Be careful to hold it vertically directly opposite the proper line on the scale, marking points with very light dots. Do not confuse the feet on the architect's scale which are numbered from either end. Remember that ½″ = 1′-0″ is not half size but one twenty-fourth size. Similarly, quarter size and ¼″ = 1′-0″, also eighth size and one-eighth inch to the foot are entirely different.

When a distance is subdivided, lay off the total first and make the subdivisions to fit.

The decimal scale is used in surveying, in diagrams, and in the graphical solution of some problems. The architect's scale is used in drawings for buildings and for the shop.

The angles in a plan are measured by a protractor; Fig. 3*c* represents a common type. In determining the amount of an angle, both lines should run beyond the protractor. In laying off an angle, the line from which the

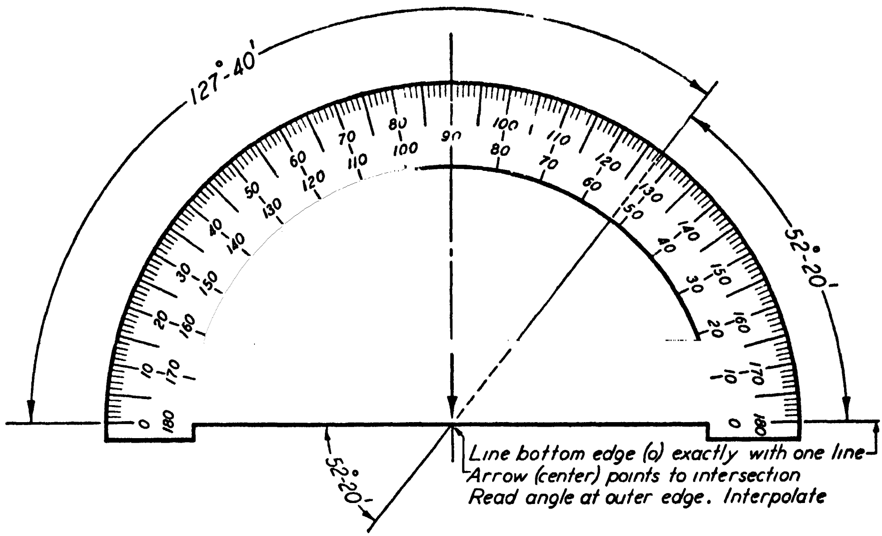


Fig. 3*c*.—A protractor.

angle is turned should project each side. Be sure to set the point which marks the center on the instrument exactly at the angle point. Care must be taken at all times that the line marking 0 and 180 degrees on the protractor is exactly on the proper line. The way in which the instrument is read is shown in the cut. Be very sure to obtain the angle properly; for example, be careful to read the angle shown as 52°-20′, not 67°-40′ or 47°-40′.

Directions in surveys are often given as angles from the north or south. Thus, in Fig. 3*d:*

N 20° E	means	from	the	north 20° toward the east.
S 40° E	"	"	"	south 40° toward the east.
S 60° W	"	"	"	south 60° toward the west.
N 78° W	"	"	"	north 78° toward the west.

For reasons that we cannot discuss here, bearings and distances should be run continuously around a subdivision, and bearings should be in the

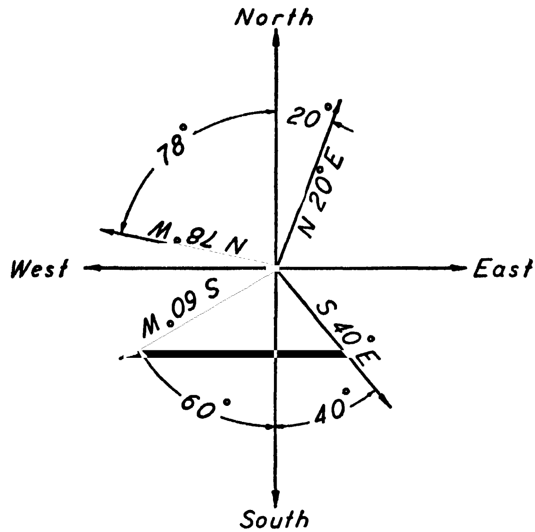


FIG 3d —Bearings

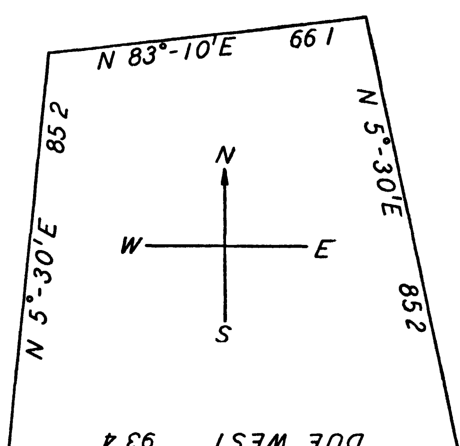


FIG 3e Bearings of a field

direction of the lettering as in Fig. 3*e*. This brings some lettering upside down, which, except in special cases like this, is very objectionable. Notice also that in surveying, distances are merely written near the line whose length is given. This practice is usual in mapping, except where it might lead to uncertainty.

LETTERING

In this lesson, we take up letters that are wholly of straight lines. Nevertheless, you should draw them free hand, making them as straight as you possibly can.

REQUIRED WORK: LESSON 3

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

3-1. What is a bearing? (A direction not a mechanical device.)
3-2. Name the two kinds of scales employed in drawing.
3-3. What instrument is used to measure angles?
3-4. State the reduction effected by the use of a scale, ¼″ = 1′-0″.

SHEET 3-1 (Fig. 3*g*)

3-5. What is the diameter of the rivet?
Note. This is the least diameter, the diameter of the rod from which the rivet was made.
3-6. Scale the overall length of the cotter pin.
3-7. Determine by scale the greatest diameter of the shaft.
3-8. How far is it vertically between the upper lengths and the lower central length of the reinforcing bar?

SHEET 3-3 [Fig. 3*h* (Scale half size)]

3-9. Determine the diameter of the large hole in the gasket.
3-10. What is the extreme length of the gasket?
3-11. State the diameter of the shaft of the inlet valve.
3-12. Obtain its extreme length.

SHEET 3-5 [Fig. 3*i* (Scale half size)]

3-13. What is the size of the largest wire that can be measured by the wire gage?
3-14. How many different wire gages are there?
3-15. What is the size of the largest hole in the drill gage?
3-16. Determine the radius of the curve at the end of the drill gage.

Sketch the following objects:

3-17. The rivet in Sheet 3-1.
3-18. The gasket in Sheet 3-3.
3-19. The center gage shown in Sheet 3-5.
3-20. A protractor.

LETTERING

Letter like the text all the letters shown therein, first 1/4" high, then 3/16" high, and finally 1/8" high.

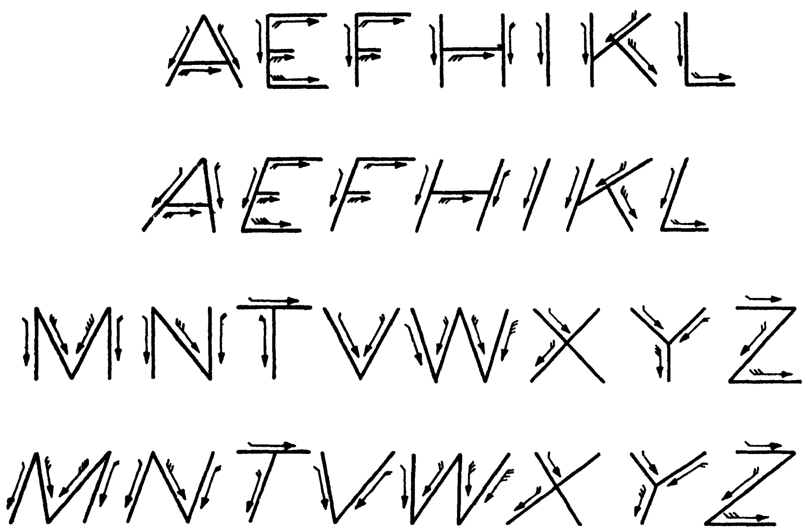


Fig. 3*f*.

SHEETS

Here again all sheets are to be studied but only one out of five is to be drawn; this is to be in pencil upon detail paper. Sheets 3-1, 3-3, and 3-5 are to be copied by measuring with a scale, multiplying by two, and then laying out from the doubled measurements. Sheets 3-2 and 3-4 are to be laid out to a scale of one inch to 80 feet. If you do not have this scale, the distances can be determined by the fact that every sixteenth of an inch represents five feet.

Be sure that cutting lines, border lines, and title are complete.

Sheet 3-1 (Fig. 3*g*)

Rivets are sometimes used to fasten pieces of metal together permanently. A short piece of a round rod is heated and the ends mashed up to the shape shown. Usually both ends are like the one at the left; however, this rivet has the right end countersunk, that is, it is shaped so that it will leave a flat surface while still holding the plate.

A cotter pin is likewise used to fasten two pieces of metal together. It is passed through a hole in each, and then a piece of bent wire called a cotter is put through the hole as shown to prevent the plates from falling off.

The reinforcing rod is used to strengthen a concrete beam. The drawing is called a line diagram, as the rod is shown by only one line, whereas there really should be two.

Note in each case that a single view in connection with the lettering is sufficient to explain fully just what the object is. In practice give enough views to make it entirely clear just what is meant but never any more; needless views are a waste of money.

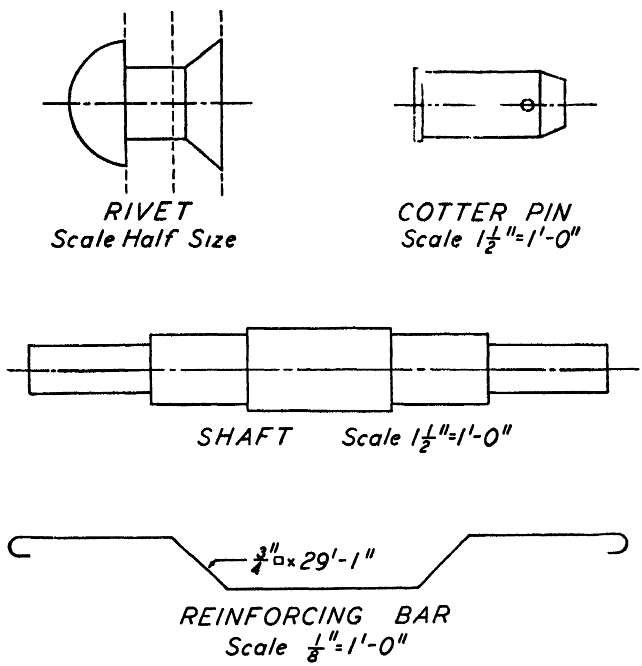


Fig. 3g.

All objects on your drawing are to be just twice as large as the cut. Hence the scales as shown in Fig. 3*g* will be doubled on your drawing:

Scale Half Size for RIVET will become Full Size on your drawing.

1½" = 1'-0" for COTTER PIN and SHAFT will become 3" = 1'-0" on your drawing.

⅛" = 1'-0" for REINFORCING ROD will become ¼" = 1'-0" on your drawing.

Sheet 3-2

A surveyor's notes contain the following data for the field *ABCD:*

AB = 426.0 feet ANGLE *ABC* = 93°-30' to the right as you look from *A* to *B*
BC = 454.5 *BCD* = 72°-42' to the right as you look from *B* to *C*
CD = 601.2

Lay out the best quarter-mile running track that you can in this area, making it so that the curves are as easy as is practicable. Make the track 12 feet wide with the quarter mile measured 18″ from the inside of the track.

SHEET 3-3 (Fig. 3*h*)

A gasket is a thin piece of compressible material used like a washer to prevent leakage at a joint. The inlet valve shown is similar to that of an automobile.

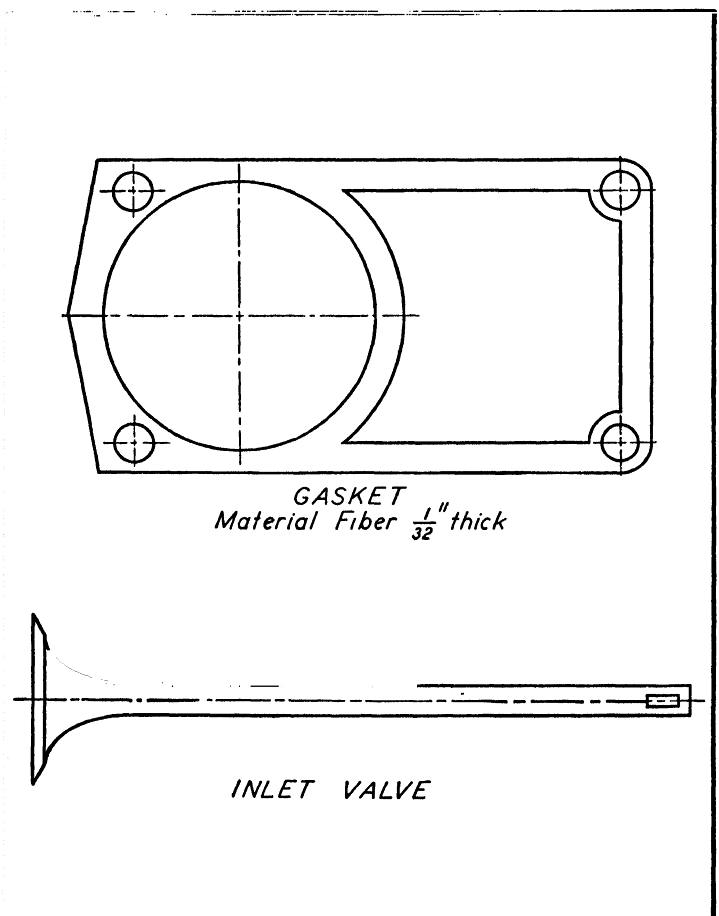


FIG. 3*h*.

The first is known to be flat, the second is made round except for the rectangular hole; hence one view for each in connection with what is known is enough.

Figure 3*h* is half size; hence when you have doubled each distance in laying out your drawing, the scale should be full size; this fact should be indicated upon your drawing.

SHEET 3-4

A surveyor's notes contain the following data regarding 8 sides of a 9-sided tract of land:

AB	Due West	225.6 feet
BC	N 36°-35′ W	243.5
CD	N 30°-23′ E	[illegible]85.4
DE	S 62°-15′ W	165.4
EF	N 41°-40′ E	318.0
FG	N 42°-15′ E	221.5
GH	S 24°-54′ E	384.6
HI	S 15°-15′ W	300.0

Plot at a scale of 80 feet to the inch, making the long edge of your sheet north and south and starting A ½″ from the bottom border line and 1½″ from the right-hand border line. Very accurate plotting is necessary to get a satisfactory result. For your answer determine the distance *IA* and the angles *HIA* and *IAB*.

SHEET 3-5 (Fig. 3*i*)

This drawing shows some machinists' instruments for measuring. Copy this drawing in pencil upon detail paper, making each distance exactly twice

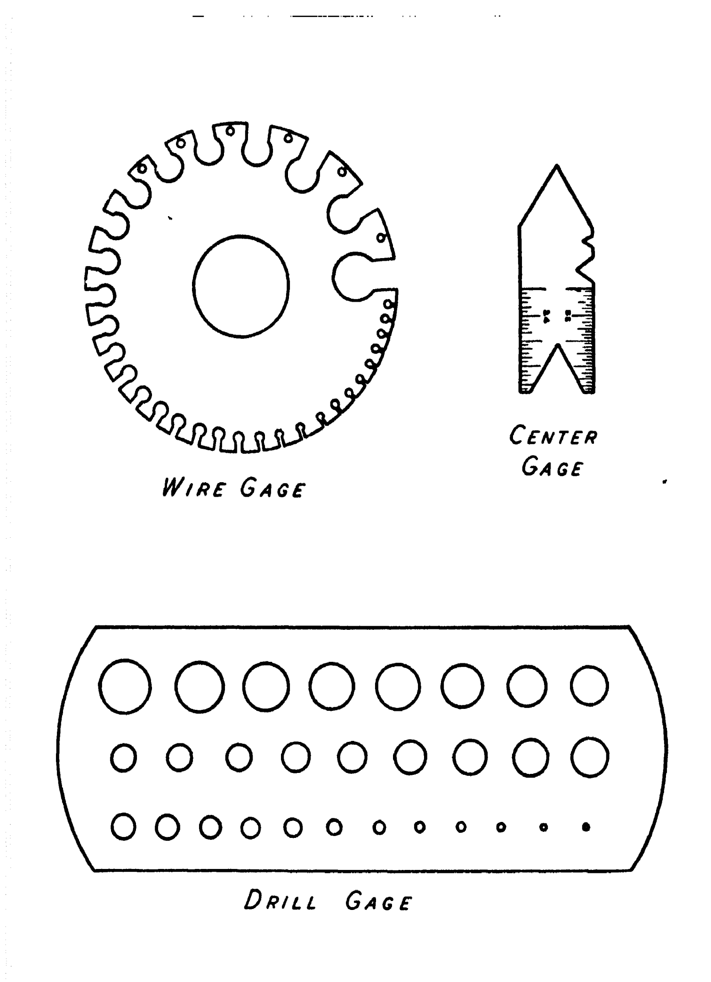


FIG. 3*i*.

the size of the cut in this book. The scale in the figure is half size; hence the scale on your drawing will be full size.

This is the end of Lesson 3. A thorough knowledge of this subdivision is essential for what follows.

LESSON 4

OBJECTS DESCRIBED BY VIEWS IN COMBINATIONS

The uses of a drawing have been mentioned in the preceding lesson; again we will emphasize that their purpose is to make entirely clear every detail of the object that is described. We also explained objects in which one view was sufficient to make them clear to a second person. For many cases, other views are needed. Where more than one view is required, there are two fundamental requirements:

In the first place, as in the preceding lesson, the views are taken "square on"; in other words, we look squarely at each face that is represented. This is important because by looking squarely at the face we get the measurements in their true sizes (or in their proportionate sizes). The square-on view is very easy for the draftsman to construct; it is also simple and easily followed by the workmen in the shop. For these reasons, the views should be drawn in this manner unless there are excellent reasons why this should not be done.

Secondly, the directions of the views are usually at right angles to one another. As the main faces of most industrial objects are at right angles to one another, this is a very natural arrangement.

The views commonly used in practice are as follows:

The Top View or Plan looks directly down at the top of the object.

The Front View or Front Elevation looks horizontally at the front of the object.

The Right Side View looks at right angles to the two preceding directions and at the right side of the object.

Similarly, the Left Side View looks directly at the left side of the object and at right angles to the direction of the top and front views.

The Bottom View looks upward directly opposite to the Top View and at the base of the object. It is best to avoid this view as it is harder to understand than the others.

The Rear View looks directly at the rear face of the object and in an opposite direction from the Front View. It is also hard to understand and it is better if it is not used except in drawings of buildings where it is a necessity in many ways.

We have thus defined six views and there are still others that might be employed. The question confronting the beginner is, "Which views should

be used?" The answer is: "Use as few as you can and those which will describe the object most clearly without any possibility of misunderstanding." The best combination is usually the Front View and the Top View; often, however, more views are needed.

Figure 4*a* shows a drawing of a brick with one edge clipped off and two holes extending through it. We have shown the four most common views:

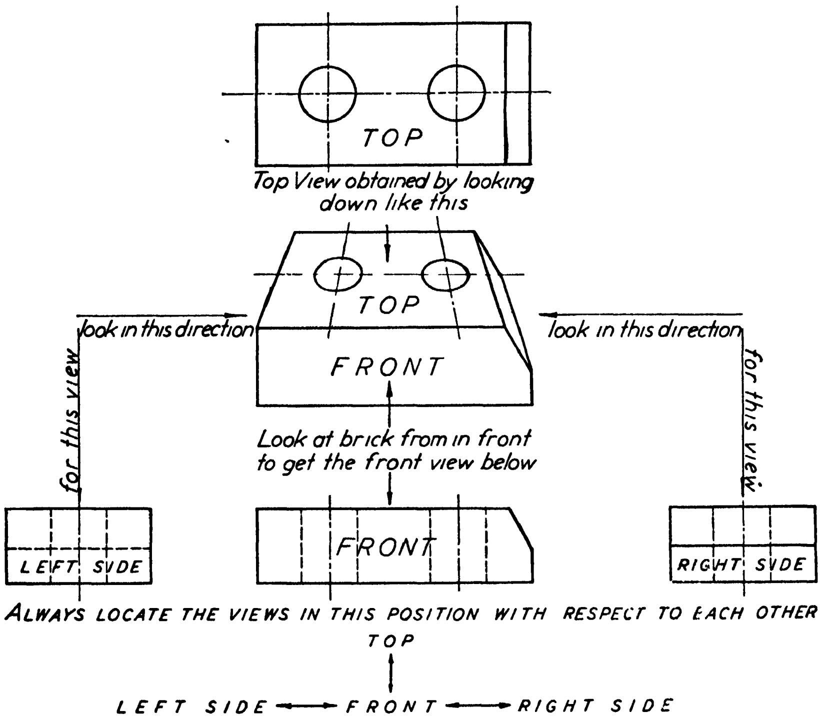


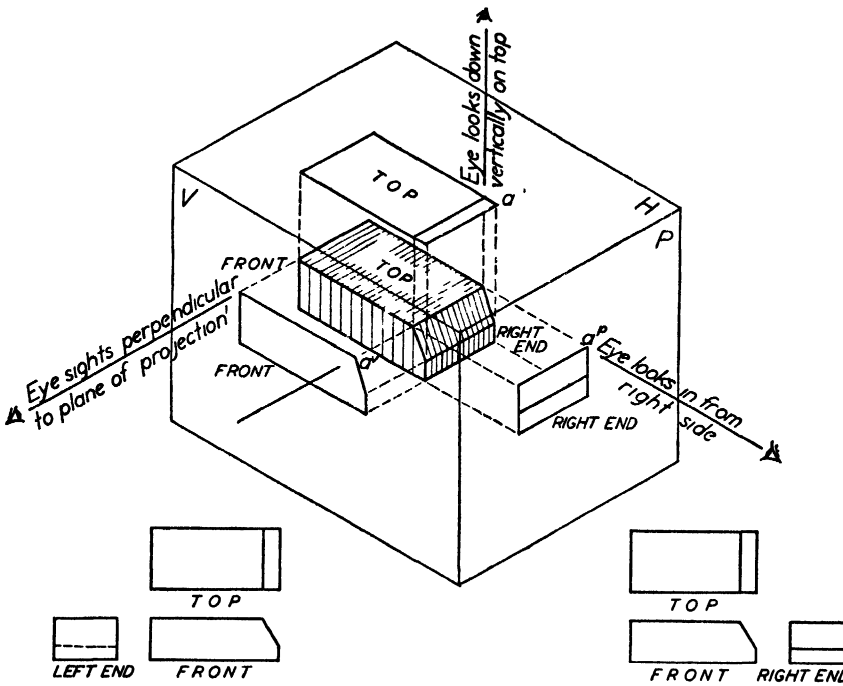
FIG. 4*a*.

the top view directly above, the front view in front, and the two end views at the side of the front view.

Some prefer to consider the drawings as projections rather than views. Thus, in Fig. 4*b* the same object with holes omitted is represented as projections upon planes made parallel to the main faces of the object. From each salient point of the object, a perpendicular is let fall upon the plane and this helps to draw the apparent outline of the object. Workmen prefer views but some students like the projection method to determine the lines and relative location of the drawing; however, the resultant drawings are the same whether the view method or the projection method is employed to work them out.

Objects like a house, an automobile, or an airplane, each have a front;

for these, the front view means only one possible drawing. However, sometimes an object does not have a front or a top. In this case, the draftsman chooses his own front and works with that as a basis.



METHOD BY WHICH THREE VIEWS OF AN OBJECT ARE OBTAINED

FIG. 4b.

POSITIONS

As shown in Figs. 4*a* and 4*b*, the top view is always placed above the front view, the right side view to the right of the front view, and the left side view to the left of the front view. Should it be necessary to employ a bottom view, it is placed directly under the front view; and should it be advisable to use a rear view, it might be placed to the right of the right side view or to the left of the left side view.

The top view has the front toward the bottom of the sheet. The right side view has the front to the left, and the left side view has the front to the right. This arrangement can best be remembered if one compares it with the unfolding of the exterior surface of a box. Remember wherever your drawings or sketches go, others will assume that this rule is followed. Similarly you must assume this rule in interpreting any drawing. Costly mistakes are likely if drawings are not placed as we have indicated.

OPPOSITION

As shown in Figs. 4*a*, 4*b*, and 4*c*, the top view is placed directly above the front view. Any given point in these two views will then be in a single vertical line. Likewise, each given point in a side view is directly opposite the corresponding point in the front view. This is easy for the draftsman to

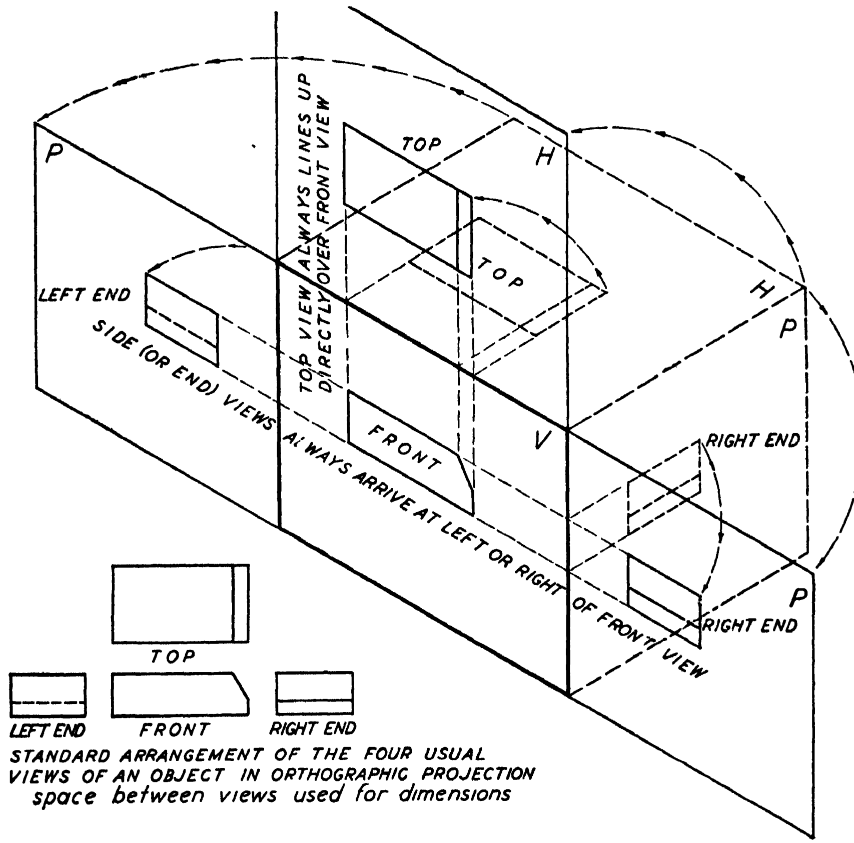


FIG. 4*c*.

make and easy for the workman to understand. For these reasons, the rules should be followed if it is at all possible. If the bottom view is given, it also should be opposite and below the front view; and if the rear view is given, it should be opposite and on a level with one of the side views. Let us call this very important statement the "Law of Opposition."

It is usually considered unnecessary to put the name of the view below it. Properly placed, the location of the drawing shows what it is.

VISIBILITY

When there is a line on the object which cannot be seen, it is shown dotted in the view in which that line is invisible. The weight of the dotted line should be less than that of the corresponding object lines, say, a third less. Dashes should be about 1/8 inch long with about 1/32 inch between them. Lay out on the margin of your sheet an ideal dotted line and then copy it as near as you can estimate without making direct measurements. As shown in Fig. 4*d*, when two dotted lines intersect, make their dashes cross. When a full line becomes invisible, start the dotted line with a space. When a line is invisible for its entire length, start the line with a dash.

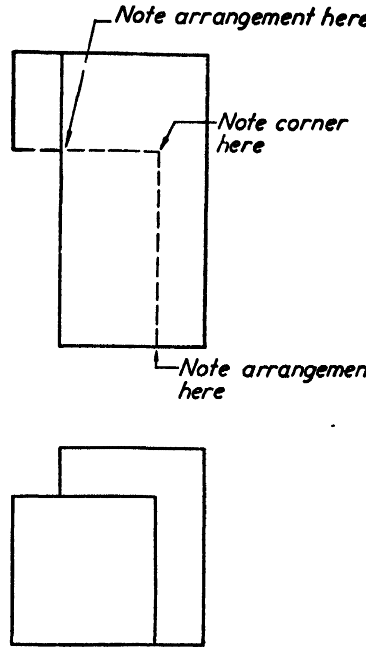


Fig. 4*d*.—Construction of dotted lines.

VISUALIZATION

From a combination of two or more views, one may form in the mind the image of any part of the structure which is represented. This is called "visualization" and we say that we "visualize" the object. This means that a man who can visualize the object can make it if he has the necessary mechanical ability. Or, if he has an object in mind, he can draw the views which will make it clear to someone else.

One must not expect to visualize instantaneously; it takes time, experience, and practice to do the work well. Look first at the front view; then glance at the side view or perhaps at the top view and get an idea of the depth of each part that is shown in the front view. Gradually, there will appear in your mind an image of the actual object.

REQUIRED WORK: LESSON 4

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

4-1. In your opinion, what two views are most frequently used in drawings?
4-2. Explain how an invisible line is represented.
4-3. What is meant by opposition?
4-4. Why is visualization important?

Sheet 4-1

4-5. How many foundation bolts are there in this footing?
4-6. What is the size of the base?
4-7. How many cubic yards will there be in 20 of these?
Note: A cubic yard contains 27 cubic feet.

Sheet 4-2 (Fig. 4*g*)

4-8. What is the diameter of the set screw?
4-9. State the greatest depth of the Woodruff key.
4-10. What are the dimensions of the smaller end of the gib head key?

Sheet 4-3 (Fig. 4*h*)

4-11. What is the height of the monument?
4-12. What is the diameter of the hole provided for the shaft in the bearing?
4-13. How many bolts are used to hold the bearing down?

Sheet 4-4, Sheet 4-5 (Fig. 4*i*)

4-14. What is the length of the rectangular hole in the post?
4-15. Determine the greatest depth of the ring (in the lower right-hand corner).
4-16. Find the extreme length of the wedge (in the upper left-hand corner).

Sketch the following objects:

4-17. The clamp washer in Sheet 4-4 and Sheet 4-5 (in the middle right-hand portion of Fig. 4*i*).
4-18. Sketch a footing similar to that on Sheet 4-1 and on similar soil with a load only half as great. Use areas half as great and depths three-quarters of those formerly employed.
4-19. A front and a side view of your automobile or that of some friend.
4-20. Front and right side view of the house in which you live.

LETTERING, Fig. 4e

Letter like Fig. 4*c* in the text the numbers 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9, both vertical and inclined. Make them first $\frac{1}{4}''$ high, then $\frac{3}{16}''$ high, and finally $\frac{1}{8}''$ high.

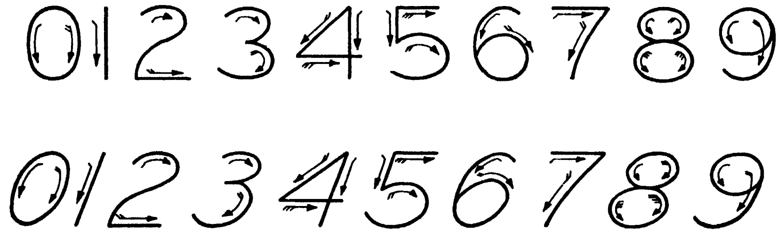


Fig. 4*c*.

SHEETS

Here again all sheets are to be studied; one out of five is to be drawn in pencil upon detail paper.

Sheet 4-1 will be described in words, and it will be your task to put this into the form of a drawing. Other sheets will be indicated by pictorial

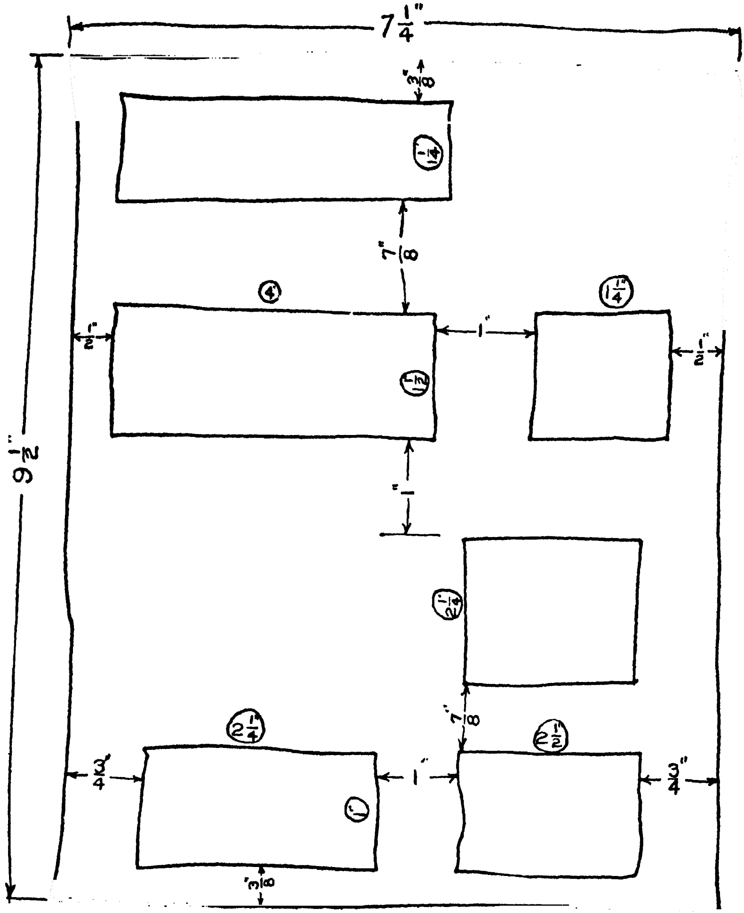


FIG. 4f.—Method of locating views.

drawings with the dimensions upon them, and you will be required to describe the object by ordinary square-on views. Do not attempt to give dimensions until you reach the next lesson.

When you have to locate drawings upon a vacant space, proceed as indicated in Fig. 4f. Lay out first the rectangle which indicates the availa-

ble space and mark upon it the dimensions. Then put the various views on the drawing about as you think they should be, and mark upon them the extreme dimensions in both directions. These measurements in Fig. 4*f* are enclosed in circles.

Next add the vertical distances on the views to find the total vertical space required; this sum subtracted from the vertical height available gives us the total amount for spaces between views. The total of the horizontal spaces between views may be obtained similarly. Then divide up the vacant space, both vertically and horizontally, into somewhat unequal parts and make those the spacing between the different views. It is desirable to make the distance between the view and the border line about ½″ but not less than ¼″; the distance between two views 1″ but not less than ½″; the distance between different objects 1½″ but not less than ¾″. If you use less than these minimum values, the sheet will appear to be crowded.

Sheet 4-1

The heavy load carried by a column is spread over the comparatively weak soil by a block of masonry called a footing. It may be gradually sloped but it is more often made as a series of gradually enlarging steps down to the final foundation.

The bottom part of a footing is 8′ square and 18″ high. The intermediate part is 5′ square and 12″ high. The upper part is 3′ square and 10″ high. Upon this rests a cast-iron base 18″ square with 4 bolts 12″ on centers in either direction, all symmetrical about the center line of the whole block. The bolts are 1½″ in diameter, 20″ long, and project 3″.

Draw front and top views of this footing at a scale of ½″ = 1′-0″.

Sheet 4-2 (Fig. 4*g*)

A key is a piece of metal inserted in a slot which is partly in a wheel or similar device and also partly in the shaft. When the key is driven into this opening it holds the shaft and the wheel rigidly in position. A set screw is turned through a tapped hole in the hub of a wheel and presses upon the shaft. It acts like a key but is not considered as strong and dependable.

A set screw, a Woodruff key, and a gib head key are shown in pictorial drawings on Fig. 4*g* at a scale of 6″ = 1′-0″ or half size. Show at full size a left side view looking at the head and a front view of the set screw; a top view and a front view of the Woodruff key, and a top view and a front view of the gib head key.

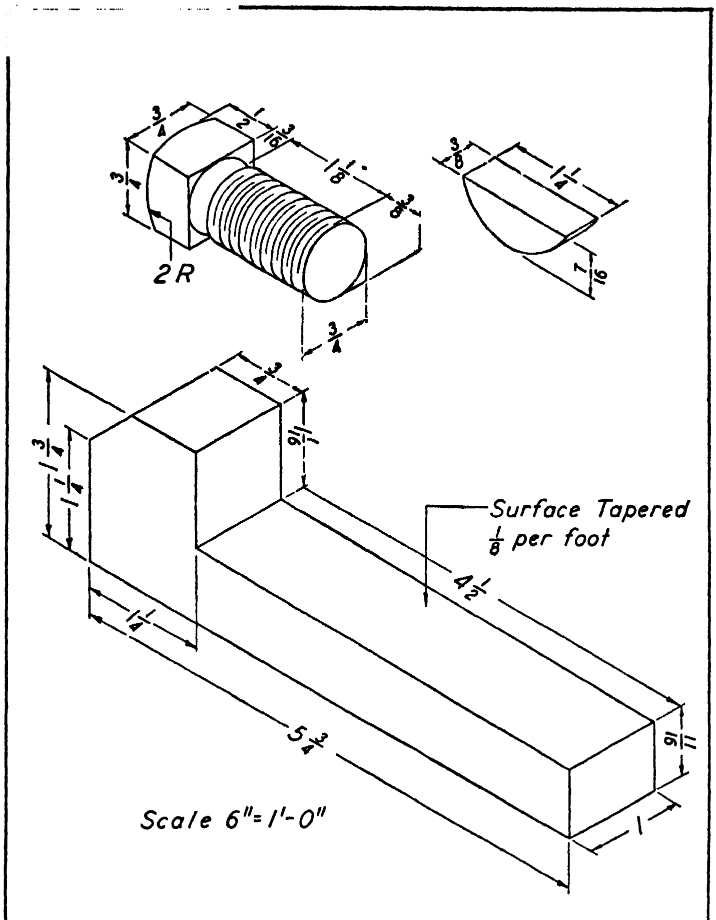


FIG. 4g – Keys and a set screw.

SHEET 4-3 (Fig. 4*h*)

A bearing is an arrangement which carries the load from a shaft to a beam or other support on which the shaft indirectly rests.

In Fig. 4*h* are shown the pictorial drawings of a monument and of a bearing with dimensions. Please draw the front and top views of the

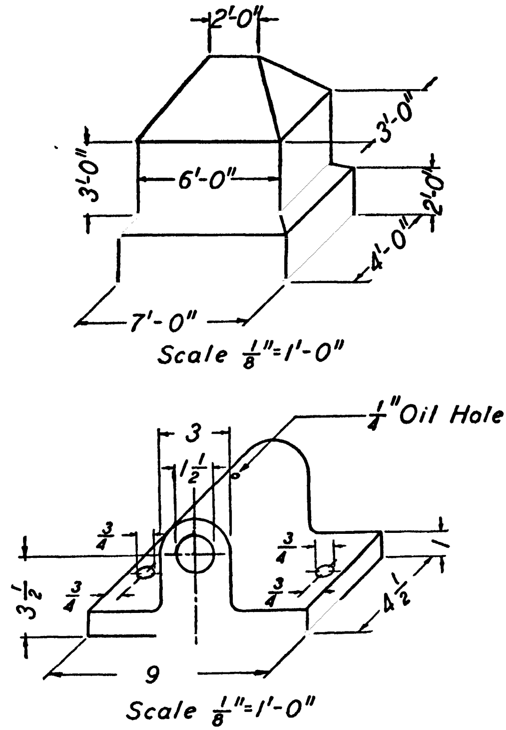


FIG. 4*h*.—A monument and a bearing.

monument at a scale of ¼″ = 1′-0″, and the front and the side view of the bearing at a scale of 3″ = 1′-0″.

SHEET 4-4 (Fig. 4*i*)

A lathe is a machine in which an axis is revolved rapidly. An object in this axis is turned to make a true cylinder by means of a tool held in the lathe. A tool post is the instrument for holding the tool.

In Fig. 4*i* are shown the essential parts of a tool post. Draw full size the post shown in the lower left-hand corner of the cut, the clamp washer shown in the middle right-hand side, and the ring shown in the lower right-hand corner. In each case, use the top and the front views.

SHEET 4-5 (Fig. 4*i*)

On this sheet show full size the front and the top views of the wedge in the upper left-hand corner of Fig. 4*i*, the front and the top views of the set

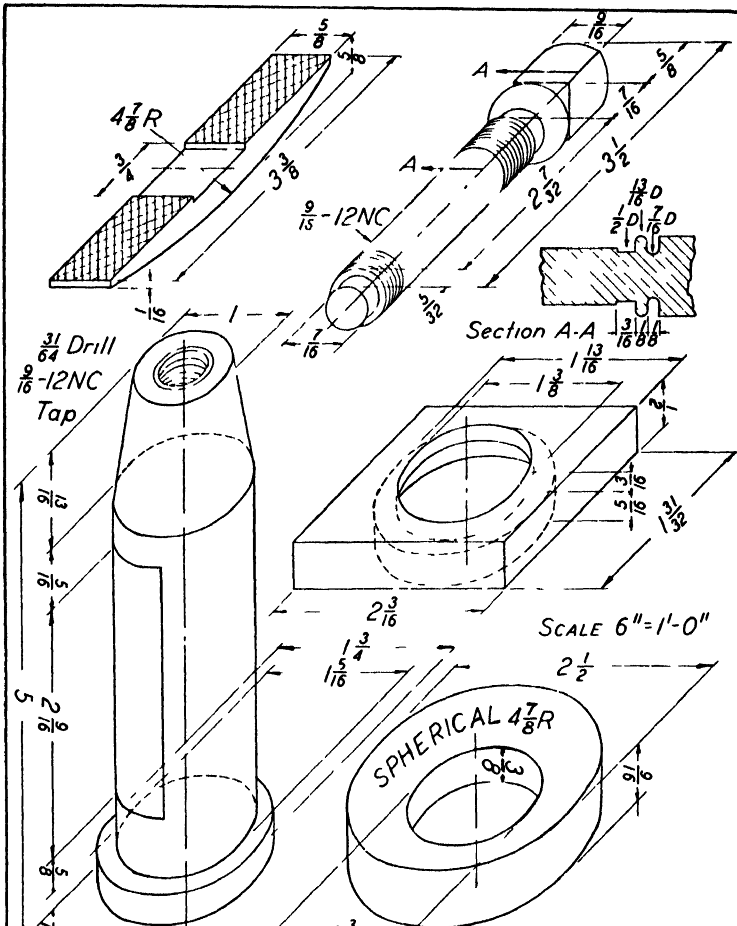


FIG. 4*i*.

screw shown in the right-hand upper corner of Fig. 4*i*; also draw a single elevation of the completed tool post with all parts put together.

This is the end of Lesson 4. Can you see clearly the meaning of the pictures and can you visualize the objects which they represent?

This would be an excellent place for a review with a two- or three-hour period allowed for a quiz.

LESSON 5

DIMENSIONING

Drawings have three main purposes:

In the first place, they are used by workmen to make the object represented. This is the principal and most important use.

Secondly, they enable the purchaser and other interested persons to find out various facts in connection with the object.

In the third place, they are employed by other draftsmen to take off quantities, estimate the cost, and perhaps to design objects that connect with the one originally drawn.

Measurements necessary to carry out these purposes are called "dimensions," and the process of putting them on the drawing is called "dimensioning." The draftsman should be extremely careful to put upon the drawing

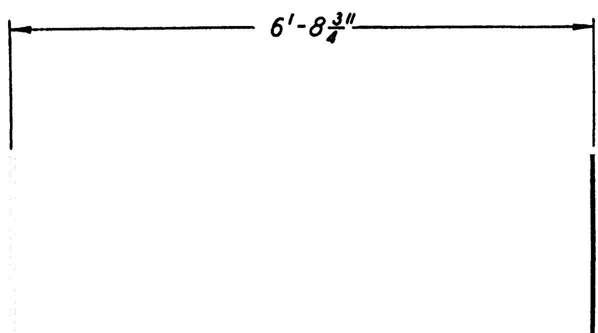


FIG. 5a.—A dimension.

every measurement that is needed; on the other hand, no distance should be given that does not fill some particular need.

Measurements are usually marked, not upon the line itself, but upon a line parallel to it, directly opposite to it and of exactly the same length. This line is called the dimension line. It is a very thin line broken at the middle for the insertion of the dimension. It is terminated by two arrowheads, each long and slender with a breadth not more than one-third of the length. The point of the arrowhead should be exactly opposite the end of the measurement. See Fig. 5a.

The extension line is likewise a very thin line extending from the point of the arrowhead to the point to which the measurement is taken. It should

stop short about $\frac{1}{16}$ of an inch from the object, just enough to make a break in the extension line. Most draftsmen prefer to extend it slightly beyond the point of the arrowhead but it should never go more than $\frac{1}{8}$ of an inch; about $\frac{1}{32}$ of an inch beyond looks best. This extension beyond the arrowhead should be kept uniform in any given drawing. A typical dimension with its dimension line, its arrowheads, and its extension lines, is shown in Fig. 5*a*.

The best place for the dimensions is between the two views to which the dimensions refer. Thus, the dimensions to the right or the left as one looks at the front of the object are best placed between the top and the front

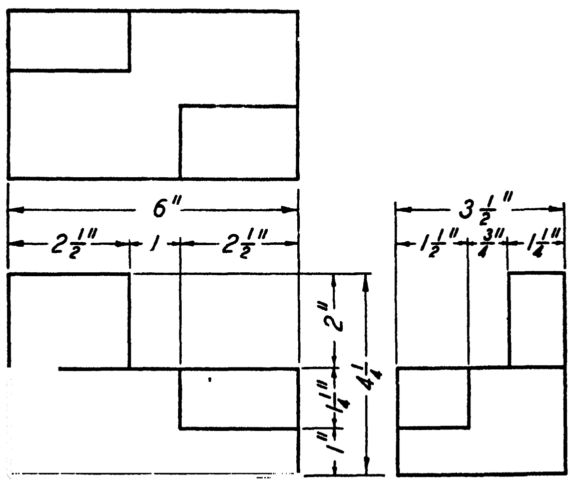


FIG. 5*b*.—An object with dimensions.

views. The amount of the height is best given between the front and the right side views, or at the right of the front view if no right side view is given. The depths, front to back, are best placed directly over one of the side views, although some draftsmen prefer to use the right side of the top view. These are the preferred locations but any of these positions may be changed to accommodate the one most important rule, "Put the dimension where its meaning will be seen most clearly."

Figure 5*b* shows the preferred locations for measurements.

A few measurements like the diameters of pipes and shafts and the dimensions of the cross-sections of timber and structural shapes are always given in inches, no matter how large the dimension is. Outside of these quantities, the mechanical practice is to give everything up to 6 feet in inches; beyond that, in feet and inches. In architectural and structural work, everything above 12 inches, except pipes, shapes, etc., is given in feet and inches. Please follow the mechanical practice for mechanical objects in this text. Fractions of inches are usually expressed to the nearest thirty-

seconds of an inch. A fraction should always be reduced to its lowest terms; thus, always 3/4, never 6/8 or 24/32. In mechanical work where great precision is required, measurements are often made decimally, perhaps to one-one-thousandth of an inch.

In architectural and structural work, it is customary not to break the dimension line but to run it straight through and to write the dimensions directly over it. For an illustration of this method, see your lettering practice for this lesson.

Special Cautions

1. A mechanic in turning a shaft or in drilling a hole uses its diameter. Hence, for his convenience, the full diameter of a complete circle must be given.

2. A mechanic in laying out a portion of a circle uses the radius; hence, give the radius of parts of a circle.

3. In making the various views of an object, a given measurement should appear but once unless there is some special reason for repeating it. Dimension once, dimension fully, and give no more.

4. Base the measurements upon important points that are determinate, like the center of a hole or some finished surface.

5. Do not use the center line of a drawing or an object line of a drawing as a dimension line.

6. Give the full length of a piece in each direction. As an apparent exception to this in an object with cylindrical ends, give the distance between the centers of the curves.

7. All horizontal dimensions should be made to read from the bottom of the sheet. In case a measurement is inclined, place it so that it is most easily read from the bottom of the sheet.

8. In case a dimension line is vertical, the dimension itself should be written to read from the right-hand edge of the sheet.

9. Where the measurement of an angle is to be given, it should first be shown by a circular dimension line. The value may be inserted

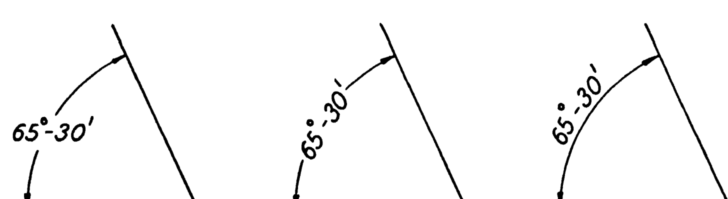


Fig. 5c.—Methods of dimensioning angles.

horizontally in a gap in the circular line, radially in a gap in the circular line, or may be written just above the circular line, all as shown in Fig. 5c. The first named is considered best.

10. When a line is subdivided into several parts, in addition to the length of each part, one should show the total of the whole length. As already mentioned, if the ends are rounded, it is best if the total dimension is given between the centers of the circles near the end rather than to the ends themselves.

11. In ordinary machine shop work, the tolerance is understood. That means that a certain measurement may vary a limited amount, say 1/64 of an inch. Where closer fits are required, the mechanic often arranges to do the work himself, making his own allowances. In mass production, however,

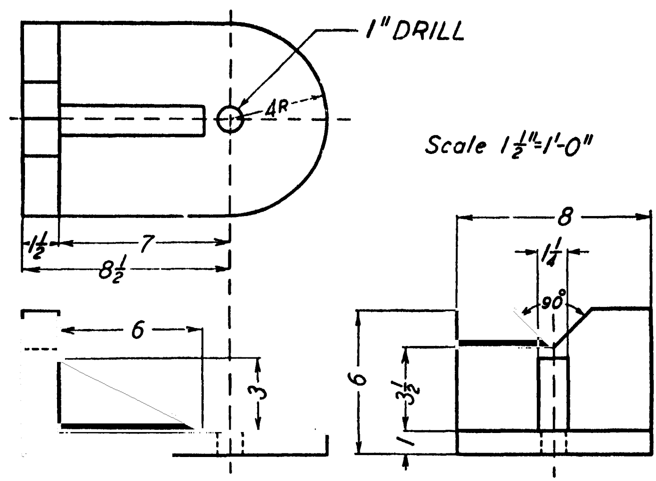


FIG. 5*d*.—Sample dimensioning.

where each piece is done separately, it becomes necessary for the tolerances to be made and determined on the drawing for each individual who makes a piece. For that reason, it is customary to put on the allowable variation either as a plus or minus distance or as two distances between which the dimensions of the piece must lie. Usually in careful work of this kind, the dimensions are in thousandths or possibly ten-thousandths of an inch. See Fig. 5*l* for an illustration of this method of dimensioning.

Figure 5*d* shows an ordinary object with its dimensions properly placed.

VELLUM OR TRACING PAPER

We have already mentioned the necessity of making many copies of a drawing and have indicated that drawings are placed upon tracing cloth for this reason. Now vellum may also be employed as a substitute; it is much cheaper both in the cost of the paper and in the time necessary to make a drawing, but it is not so permanent.

Vellum is a thin transparent paper through which the drawings underneath may be readily seen. Also the rays of light pass through it, making a blue print possible. However, it is much weaker than tracing cloth and is very easily torn; the edges of a drawing that is used for several days are quite likely to be badly frayed. Folding or crinkling hurts the paper and is very likely to show on the blue print. It is entirely ruined if any water gets on it; even the perspiration of the hand will spoil the appearance of the blue print of the drawing.

Work upon vellum is usually done in pencil. In order that a good blue print shall be made from the drawing, it is necessary that the lines be black and opaque, and that they shall not allow the light to pass through them. For the object lines, use a 2H pencil, taking special pains to make every line black, clear, and distinct. On the other hand, the dimension lines, the center lines, the extension lines, and the cross-section lines where it is desired to make them faint, should be drawn with a 4H pencil and not made too heavy. Care must be taken, especially with the harder pencil, not to press so hard as to tear the paper. In working on an ordinary board, it is necessary to have underneath something like a piece of detail paper so that the pencil will not punch through the paper occasionally when there is a tack hole underneath.

Drawings are made directly upon the vellum; they are copied from sheets underneath only when it is necessary to change or revise an old view.

TAKING DIMENSIONS FROM A DRAWING

In practice one will find all sorts of arrangements, from carefully made scale drawings without dimensions to sketches without a pretense to scale but with dimensions. The most common arrangement is to keep it approximately to scale but to dimension it and to depend upon the dimensions altogether.

What, then, is the student to do when handed a drawing? There are two very important rules:

Do not scale a drawing when dimensions are available.

Follow the practice of the company making the drawing, usually your own company. Sometimes the methods followed by outside companies are already known or are indicated by correspondence. An experienced man can tell a great deal from the drawing.

BREAKS

To be valuable a drawing without dimensions must be to scale. However, with dimensions it is not so important and scale is often disregarded. The best practice is to make the drawing to scale; if at any place it is not

to scale, the fact is shown by breaks. These usually indicate that a portion of the piece is not shown. As will be quite evident, this must be a part for which there is no unusual construction.

Typical breaks are shown in Fig. 5*e*.

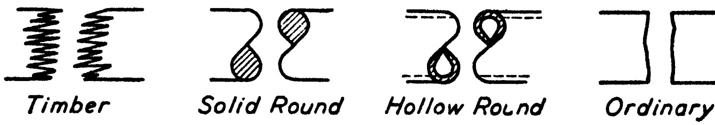


FIG. 5*e*.—Typical breaks.

REQUIRED WORK: LESSON 5

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

5-1. What three classes of persons use dimensions?
5-2. When should the radius be given and when should the diameter be stated?
5-3. Describe the dimension line.
5-4. How does practice in dimensioning structural objects differ from that for mechanical objects?

SHEET 5-1 (Fig. 5*j*)

5-5. What is the tread of the stairs shown in the figure?
Note: The tread is the portion on which the foot stands. The length of the tread is 3′-4″ but it is the other dimension that is required. The dimensions here are given according to the architectural practice.
5-6. What is the rise of the stairs?
Note: The rise is the vertical height between two treads.

SHEET 5-2 (Fig. 5*k*)

5-7. What is the extreme height of this jig? (This is the longest dimension.)
5-8. State the diameter and the length of the upper circular horizontal hole.
5-9. Determine the diameter and the length of the lower horizontal hole.

SHEET 5-3 (Fig. 5*l*)

5-10. What is the extreme length of the tappet valve?
5-11. Determine the largest diameter of the valve.
Note: One of the dimensions is the largest permissible amount for the largest diameter, and the other is the smallest permissible amount. Please give both.
5-12. What inside diameter of the valve has the greatest length?
Note: Give the value and the allowable variation.

SHEET 5-4 (Fig. 5*m*)

5-13. State the extreme length of the dog.
Note: This is the upper figure on the sheet.
5-14. State the size of the hole for the pin in the clevis nut.
Note: This is the lower object in Fig. 5*m*.

SHEET 5-5 (Fig. 5*n*)

5-15. State the three extreme dimensions of the rest for the jack.
Note: This is the upper figure in the sheet.

5-16. What is the size of the cross section of the recess for the handle in the lever in the lower part of the sheet?

SKETCHES

5-17. A shaft is 2″ in diameter for 6″, then 3″ in diameter for 14″, and finally 1½″ in diameter for 8″. Sketch with dimensions according to the mechanical system.

5-18. Sketch the shaft just mentioned and dimension it but use the structural system of dimensioning.

5-19. A block is 3″ long, 1½″ high, and 2½″ deep; a plane cuts 1″ from its length, ¾″ from its height, and 1½″ from its depth, all on the front upper right-hand corner. Sketch and dimension the figure.

5-20. Sketch and dimension the footing of Sheet 4-1.

LETTERING

Copy as closely as you can the work in Figs. 5*f*, 5*g*, 5*h*, and 5*i*. Note especially that Figs. 5*g* and 5*i* are dimensioned according to the struc-

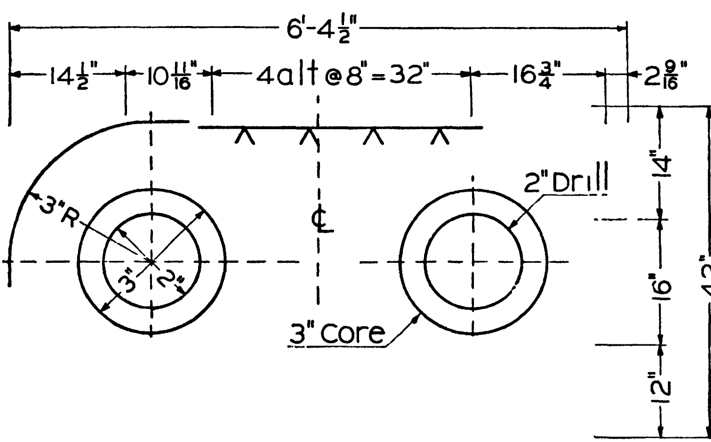


FIG. 5*f*.—Typical dimensioning—vertical letters—mechanical method

tural and architectural engineers' standard. Use this only on structural, architectural, and related objects. In Figs. 5*f* and 5*h* there is a character which looks like a *c* written across an *L*. This is an abbreviation for center

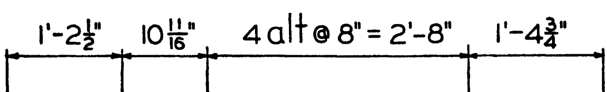


FIG. 5*g*.—Typical dimensioning—vertical letters—structural method.

line. Just above it are marks which look like a *v* turned upside down. These indicate that the surface at the points of the *v* are to be smoothed off

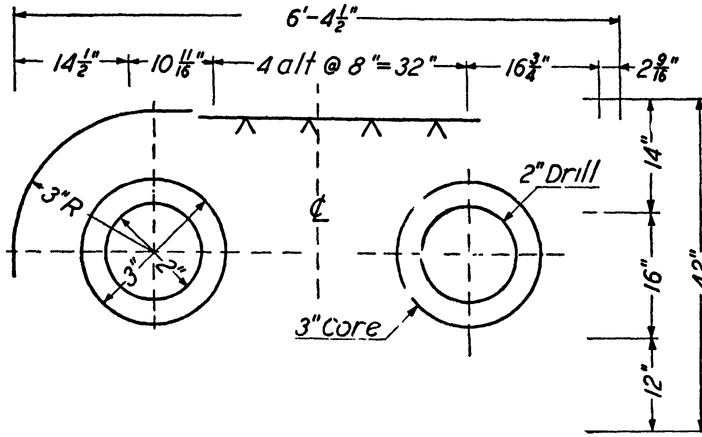


FIG. 5*h*.—Typical dimensioning—inclined letters—mechanical method.

by a planer or similar machine. Directly above this, also in Figs. 5*g* and 5*i*, is the expression "4 alt @ 8″ = 32″." This means that we have 4 spaces which are staggered or shifted from one line to another, each of them 8″ long, making a total of 32″.

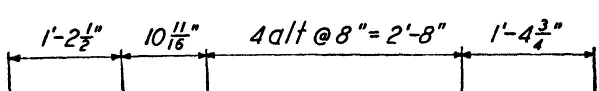


FIG. 5*i*.—Typical dimensioning—inclined letters—structural method.

SHEETS

In drawing up a sheet, first be very careful to get the various views properly spaced so that there is room enough between them for the dimension lines. A drawing looks best when the dimension lines are spaced about ¼″ apart; however, they should never be placed nearer the object nor nearer a border line nor nearer one another than 3⁄16″. If there are several dimension lines between two views, try to space them uniformly, not measuring them but making them the same by eye. The overall dimensions come farthest from the view so that the dimension line that represents the overall length will not have to cross the extension lines representing the divisions of the object. At intervals, compare your drawing with those given in the text and perhaps other places; differ from them only when there is adequate reason for doing so. As you place dimensions upon the

drawings, try to think of the work that the man must do to measure those dimensions and see that they are given in a way that is most convenient for him.

All sheets in this lesson are to be dimensioned and drawn with pencil upon vellum. Most future drawings, either in this course or in practice will likewise be dimensioned. Be careful in both places to be thorough and complete but do not repeat.

Sheet 5-1 (Fig. 5j)

Draw front, top, and right side views of the concrete steps shown in Fig. 5j. Place upon the drawing in letters about 3⁄16" in height, "Scale ½" = 1'–0"."

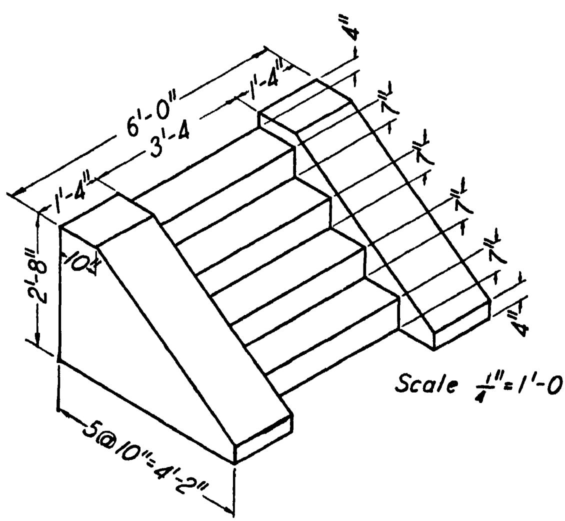


Fig. 5j.—Concrete steps.

Sheet 5-2 (Fig. 5*k*)

This drawing represents a jig. This is a term used to cover any arrangement to guide a tool or to form a pattern for the workman to follow.

Draw at a scale of 6″ = 1′-0″, top and front views of this jig, choosing the side 3½″ in extreme height by 12½″ as the front.

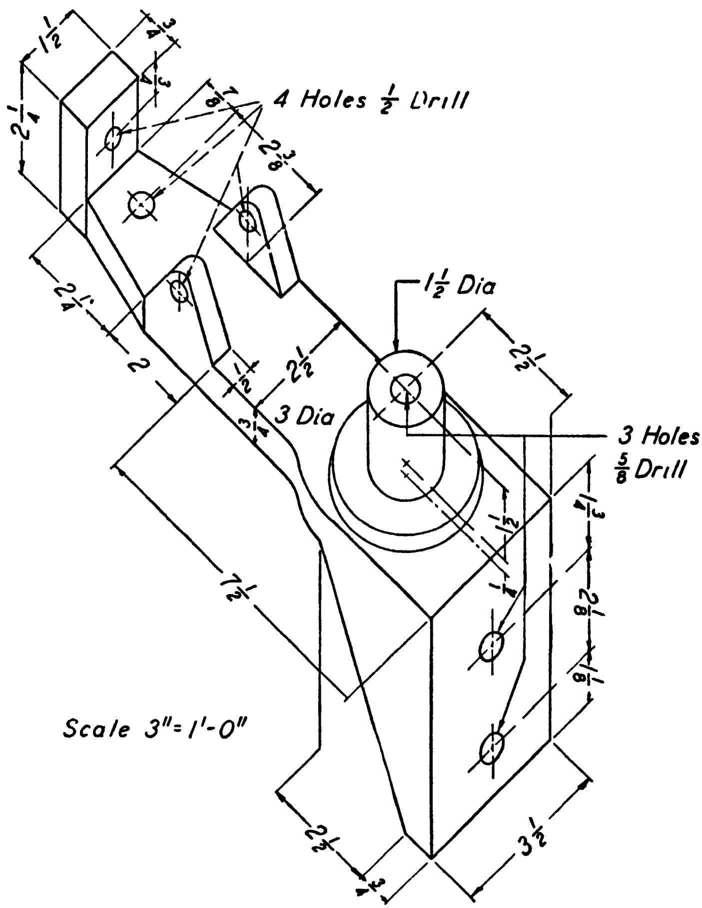


Fig. 5*k*.—A jig.

Sheet 5-3 (Fig. 5*l*)

This is a drawing of a type of valve used in automobiles.

Draw and dimension at double size the valve shown in Fig. 5*l*. When any side view is the same, a single view is enough to fully determine the object for one who is familiar with this kind of a valve. Be sure to state the tolerances and allowances as they are given on your pictorial drawing.

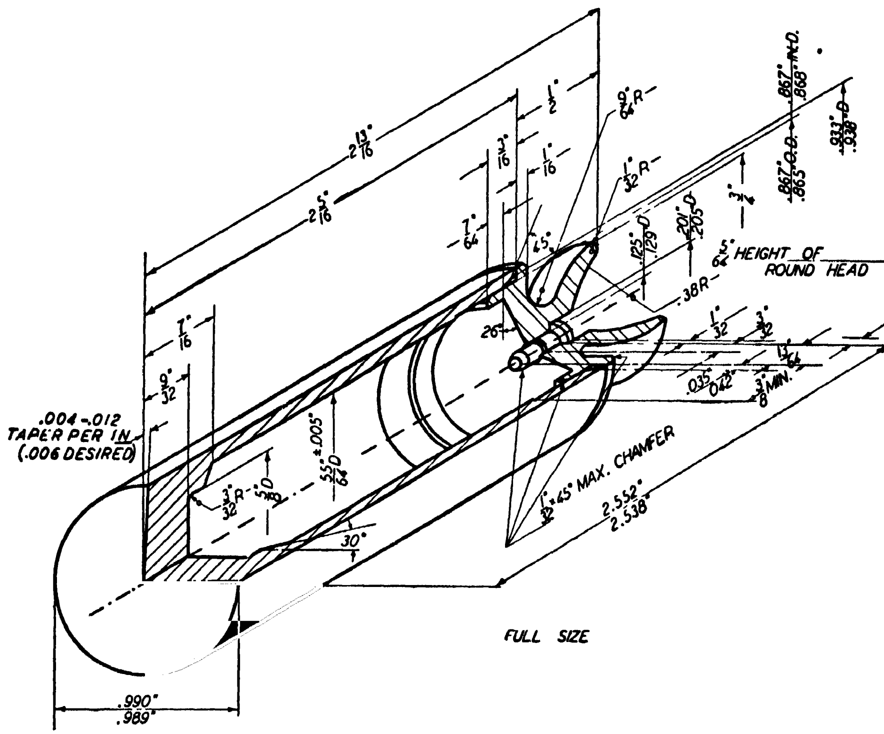


Fig. 5*l*.—An automobile valve.

SHEET 5-4 (Fig. 5*m*)

The upper figure in Fig. 5*m* is a dog. This is a piece of iron or steel that is clamped down to hold an object in position while it is being worked on

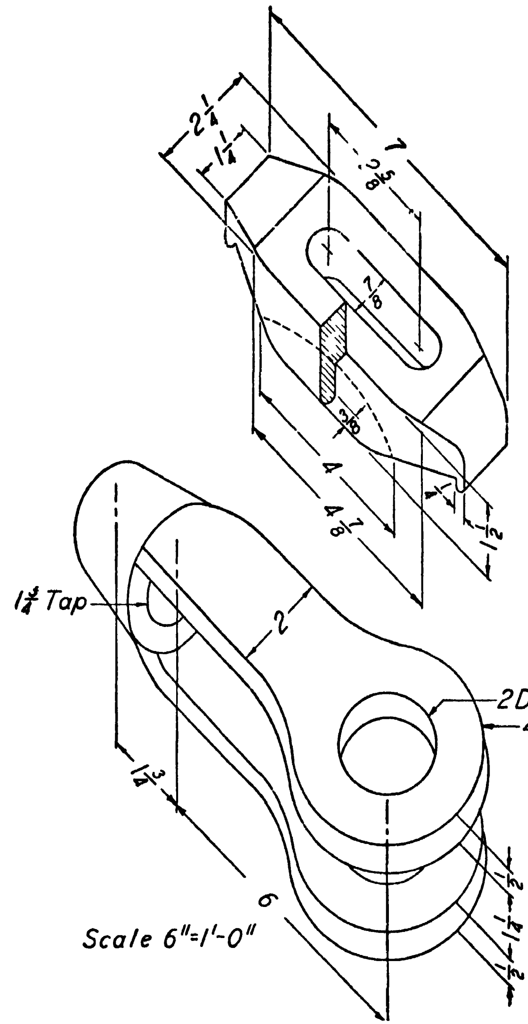


FIG. 5*m*.—A dog and a clevis nut.

by a machine. The lower figure is a clevis nut which is used to connect the screw end of a rod to a pin.

Draw both objects half size; in each case give a top and a front view.

SHEET 5-5 (Fig. 5n)

The lower figure represents an end of a lever for an automobile jack. The upper figure is a rest for the jack.

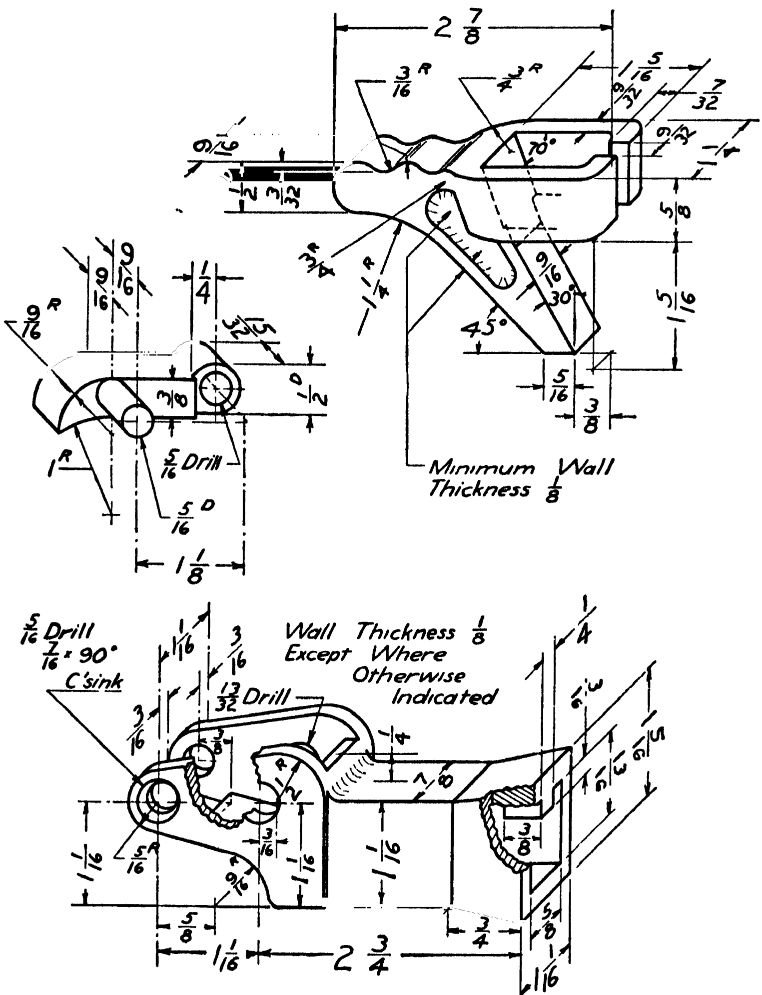


FIG. 5n.—Parts of a jack.

Draw a top and a front view of each object. Make the scale full size. There is no need to give the scale on the drawing if it is dimensioned and is made full size.

This is the end of Lesson 5. Be sure that you have given your dimensions neatly, correctly, and in a way that will help the workman.

LESSON 6

LETTERING AND DRAWING IN INK

INDIA INK

India ink is carbon held in suspension. It dries very rapidly when exposed to the air; hence if a bottle is left uncorked for very long, the ink will not run properly and it must be thrown away.

Ordinary ink should not be mixed with India ink in any manner; neither should the two be used for any tool. Ordinary pens or right-line pens that are used for both are likely to be spoiled for either fluid thereafter.

LETTERING IN INK

As pens are manufactured, they may have a bit of oil upon them which will prevent their working properly. To remove this oil, the pen may be held just a second in the flame of a lighted match. Some draftsmen prefer to put the clean pen between the lips and then wipe it thoroughly with a rag.

The ink should be spread upon the pen in a thin film, using the stopper of the bottle. If there is not enough ink, the pen soon runs dry; if there is too much, it is likely to move down onto the paper and make a blot. It is hard to get the right amount on the pen by dipping it into the bottle. Furthermore, the ink is likely to get on the pen holder and be transferred from the pen holder to the hand and from the hand to the drawing.

The pen must be wiped frequently; otherwise, it becomes gummy through the deposit of dried ink. Good lettering is impossible unless the pen is kept clean.

In ordinary lettering such as is taught in this course, lines are made at a single stroke. That is, they are made once and are not, in general, retouched. Try to work steadily ahead and avoid going over the lettering a second time. This is especially important if the student is engaged in commercial work where he is expected to turn out a large amount of drawing.

In lettering, the draftsman should brace himself lightly against the desk on which he is working. The lettering arm should be supported at the elbow and at the side of the hand, also at the little finger. The lettering is done with the pen held between the thumb and the first two fingers, the motion necessary being made entirely by these. As one progresses, the edge of

the hand and the elbow are slid along from point to point. Do not form the habit of turning the drawing, because this cannot be done with the large sheets customary in practice. Learn to make the stroke in any direction from the position of the hand and arm as given.

It is essential for the type of lettering shown in this text that the width of the line be kept the same in any given bit of work. Now the width of the line varies with:

Width of the pen.
Pressure upon the pen.
Amount of ink on the pen.

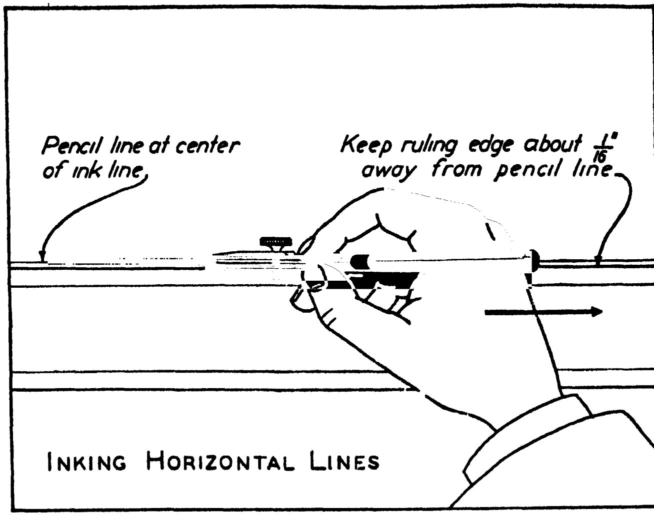
To keep the width of the line uniform:
Use the same pen for any given bit of lettering.
Keep pressure small and constant.
Maintain only a film of ink on the pen.

As a rough rule to which there are many exceptions:
When the lettering is less than 1/8" high, use a fine pen (Gillott).
Between 1/8" and 3/8", use a stiff, fine point.
When height is more than 3/8", use a ball point.

INKING WITH THE STRAIGHT-LINE PEN

First move the nibs the right distance apart; insert the wiper between the nibs and turn the pen around twice. Then, as the wiper is withdrawn, it cleans all surfaces. Next, put about 1/4" of ink in the pen, using the stopper of the bottle for this purpose. The outside of the pen should be wiped clean to remove any possible bits of ink. All specks of dirt and eraser crumbs should be dusted off the paper before the inking is started.

The position for inking is similar to that for penciling, as is shown in Fig. 6*a*. The body is braced lightly against the desk. The arm is rested upon the drawing board, and the edge of the hand and the little finger are slid lightly across the surface of the board to correspond with the movements of the pen. The pen itself is held between the thumb and the first two fingers. As the motion of these enables one to control accurately the position of the pen, this is a very necessary arrangement. The screw should be turned away from the draftsman, while the pen itself must be kept perpendicular to the paper except that the top is tilted slightly forward in the direction of the motion. The space between the nibs should be parallel to the edge of the ruler or T-square. If the pen is not kept in the plane perpendicular to the paper, only one nib will make contact and an irregular line is likely to result. There is likely to be additional trouble if the pen tilts in toward the triangle or T-square as the ink may flow underneath, making a bad blot.



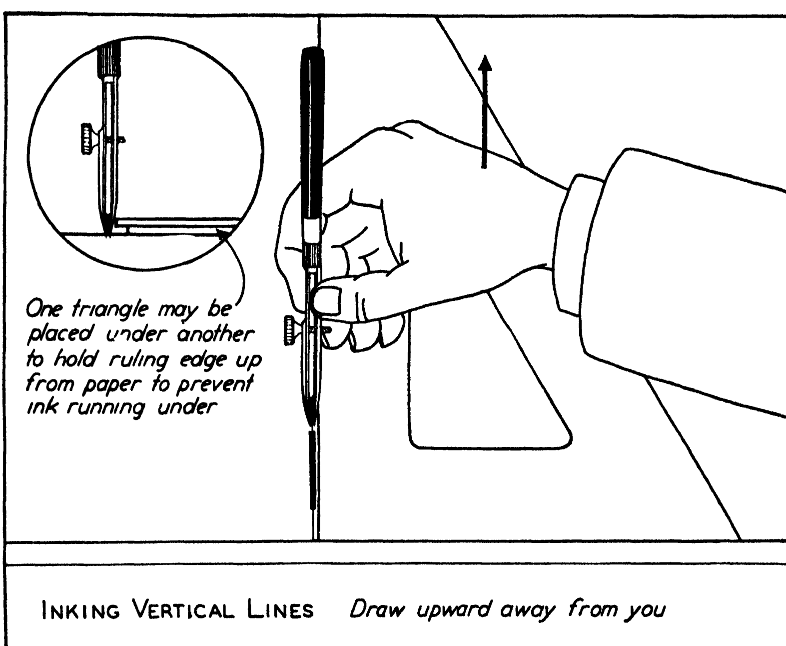


FIG. 6a —Positions in inking.

If the ink does not flow readily, it may be made to do so by lightly pressing the nibs of the pen to the back of a finger. The moisture on the skin helps to soften up the ink which is partially dried at the point. In inking a pencil line, be careful to make the middle of the larger ink line correspond with the pencil line underneath the ink.

Before drawing any lines on the finished sheet, it is well to try the thickness of the line on a piece of scratch paper. The beginner should test himself out very thoroughly before starting to use ink. A practice drawing

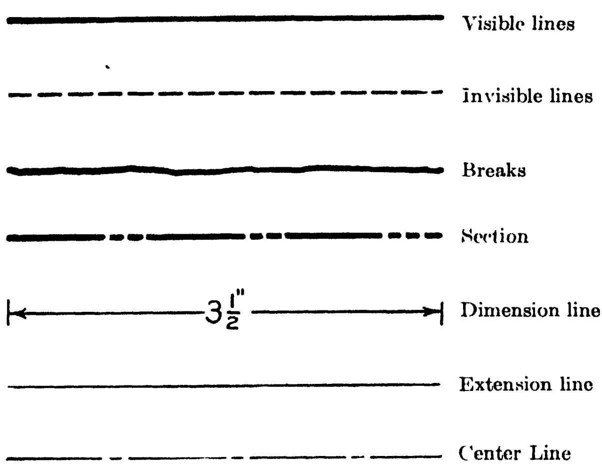


FIG. 6*b*.—The alphabet of lines.

or several practice drawings on paper similar to that used for the finished article will be a very good investment for the person who is making his first drawing in ink.

It is customary for a draftsman to show certain lines in certain ways, the arrangement for this purpose being called the "alphabet of lines." Such an alphabet is shown in Fig. 6*b*. Please follow this carefully throughout the entire course.

Heavy Lines

When the nibs are wide apart, the least trifle will allow all the ink to come down at once, leaving a large blot on the drawing. Also, one must be careful not to let the pen stay in one spot for even a second, as this is likely to cause an enlargement of the line.

To avoid these unfortunate accidents, keep the pen moving steadily. This precaution becomes especially important when you run into fresh ink at another line. When the line that you are drawing ends at fresh ink, the pen should be brought up very promptly; the least delay is likely to cause trouble.

The following are the principal causes for blots in making heavy lines:

1. Trying to make a line that is wider than is possible at a single setting of the pen.
2. Too much ink in the pen. Be very careful with a heavy line when there is more than ¼ of an inch of ink between the nibs.
3. Tipping the pen over so that the ink feeds directly under the triangle or T-square.
4. Staying too long in one place, especially where there is another fairly fresh line.
5. Moving the triangle or the T-square over fresh ink. When you have just finished a line be careful to move the triangle or T-square parallel to the line for an inch or two until it has cleared the line.

Light Lines

When inking thin lines, be sure that the pen is thoroughly clean, have everything ready, start at once, and keep drawing until the ink runs out. If the ink is slow in starting, just touch the nibs to the back of a finger.

Sometimes the pen is dull and must be sharpened before good work can be done. Occasionally the ink has dried to an extent where it does not flow properly. However, the usual cause in cases of this sort is an excessive pressure of the pen against the straight edge, thus closing the nibs. Once this has been done, clean out the pen and start again.

Blots seldom occur with light lines because they dry almost as fast as they are put down. A beginner is likely to use lines that are too heavy, or if he tries to make light lines there is difficulty in getting the pen to work at all.

Circles

The process of inking circles in many ways resembles that of making circles in pencil; there is also some resemblance to the use of the right-line pen in inking.

First, adjust needle point until the end of the pen is halfway in length between the shoulder and its points. Then set the nibs so that the pen will make a line of the required thickness; next set the compass to the required radius; at the same time, the handle, the point, and the pen should be perpendicular to the line connecting the point and the end of the pen. In making the circle, turn the compass clockwise, inclining it forward. In general, the difficulties in making heavy lines and also light lines with a right-line pen are encountered in compass work. However, there is less trouble because of the fact that the setting of the compass eliminates some of the difficulty. Be sure to wipe the pen both before and after filling.

Irregular Natural Curves

These should be drawn free hand with a ruling pen.

Irregular Artificial Curves

Usually the curves in objects are made and are intended to be made with gradual changes. Whatever they are, the drawings should reproduce conditions faithfully. First, draw the curve as it is or as it is intended to

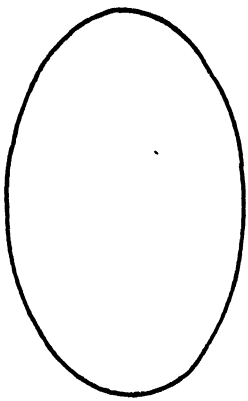


Fig. 6c.—An ellipse, poorly drawn.

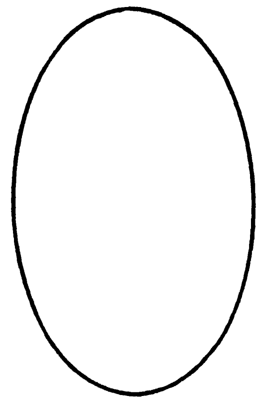


Fig. 6d.—An ellipse, properly drawn.

be, in pencil. Sometimes, points are located to represent the curve; in such cases, try to draw a smooth curve through these various points. Then lay over the pencil line an irregular curve, matching the curve as far as possible, being sure that the mechanical curve is tangent where it should be. Do not ink quite so far as the instrument fits, but stop about ¼″ short at either end; be sure that the irregular curve matches what is already drawn as well. In Fig. 6c, we have shown a poorly drawn ellipse and in

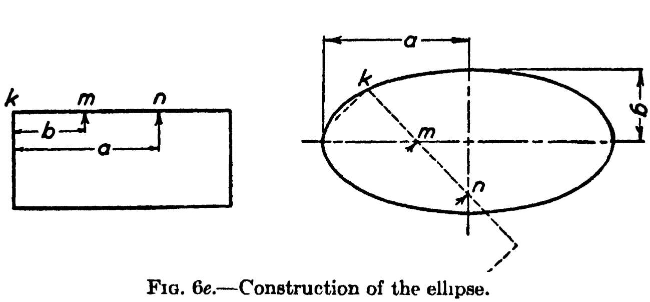


Fig. 6e.—Construction of the ellipse.

Fig. 6d, one which is as it should be. You will not need to read the titles to know which is which.

To make an ellipse, given the two axes:

Select a piece of paper with a straight edge and mark upon it the two given semi-axes a and b as shown at the left in Fig. 6e. Next place it on the

axes as shown at the right so that m is on the longer while n is on the shorter; then k will be a point on the curve as seen at the right. In this way locate some six or eight points on each quarter of the ellipse.

To make a parabola, given the chord l and the maximum ordinate h:

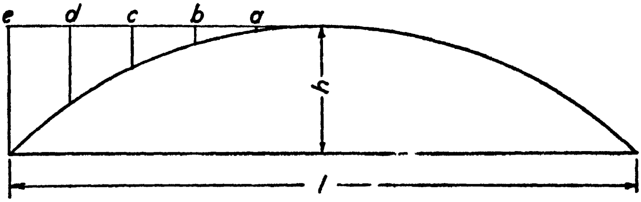


FIG. 6f.—Construction of the parabola.

Divide each half into a number n of equal lengths, say, 5, that is, n in this case is 5. Then, as in Fig. 6f, the ordinate at $a = \left(\frac{1}{n}\right)^2 h = \frac{1}{25} h$ in our example. The next ordinate at $b = \left(\frac{2}{n}\right)^2 h = \frac{4}{25} h$; at c, $\left(\frac{3}{n}\right)^2 h$; at d, $\left(\frac{4}{n}\right)^2 h$; and at the end e, $\left(\frac{5}{n}\right)^2 h = h$. Lay out the same values on the other side and connect by a smooth curve.

Inking should be done in this order:

Full circles
Dotted circles
Full irregular curves
Full object lines
Dotted irregular curves
Dotted object lines
Center lines
Dimension and extension lines
Cross hatching

Erasures

When any line, lettering, or anything else in ink is to be removed, blot it as soon as possible unless it is already dried. (Never use a blotter on a line that is to be left in. A blotted line presents a poor appearance and prints very faintly or not at all.) Then let the line dry about five minutes. Finally, put a hole in the eraser shield over the ink to be erased and go at it with a hard pencil eraser. Knives and razor blades tear the surface of the paper and make it impossible to do good work when a line is to be drawn over the torn surface.

REQUIRED WORK: LESSON 6

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

6-1. What determines the thickness of the lines made when using an ordinary pen?
6-2. Explain how erasures should be made.
6-3. State the usual difficulties when one is drawing light lines.
6-4. Outline the procedure for drawing an irregular artificial curved line.

Sheet 6-1 (Fig. 6*g*)

6-5. What is the maximum length of this block?
6-6. Determine its overall height.
6-7. What is the inner angle for either V?

Sheet 6-3 (Fig. 6*h*)

6-8. What is the vertical distance between the center lines of the two holes?
6-9. State the length of the ½″ drill hole.
6-10. Determine the length of the ¾″ tapped hole.

Sheet 6-4 (Fig. 6*i*)

6-11. What is the length of the ⅜″ tapped holes?
6-12. What is the largest width of the tool that may be held in this tool holder?
6-13. Compute the area of the base of the tool holder.

Sheet 6-5 (Fig. 6*j*)

State the numbers at which the following fittings should be employed:

6-14. Tee.
6-15. Y.
6-16. Quarter turn.

Sketches

Consider questions 6-17, 6-18, 6-19, and 6-20 to be the sketching of one of the sheets of Lesson 6, in no event using as a sketch the drawing which you actually make.

LETTERING

Copy the figures 5*f*, 5*g*, 5*h*, and 5*i*, this time in ink. Make the object lines heavy as shown in the alphabet of lines, and the extension and dimension lines very thin. The numbers must be done freehand. If you have not done much lettering, it might be best to make them first in pencil. However, as you acquire more experience you should gradually accustom yourself to getting along without this aid. The skilled draftsman finds that penciling is an annoyance rather than a help, as it prevents him trom seeing clearly the shape of the letter he is making in ink.

SHEETS

All drawings required in this lesson should be made in pencil upon vellum and should be completely dimensioned. If at all possible, the pencil drawing that you made in the preceding lesson should have been blue printed. If the lines representing objects in the print are faint and the numbers are hard to read, you must realize that you are not making the corresponding marks as black as they should be. Possibly the dimension lines appear as heavy as the object lines or, as we say, the drawing lacks "contrast." In a print, the dimension and extension lines should appear merely as faint, barely traceable lines.

When you have finished your drawing, compare it and the dimensions that you have placed upon it with some well-made drawings and see how it appears.

SHEET 6-1 (Fig. 6*g*)

A V block is an arrangement for holding in position objects like shafts while they are being worked upon.

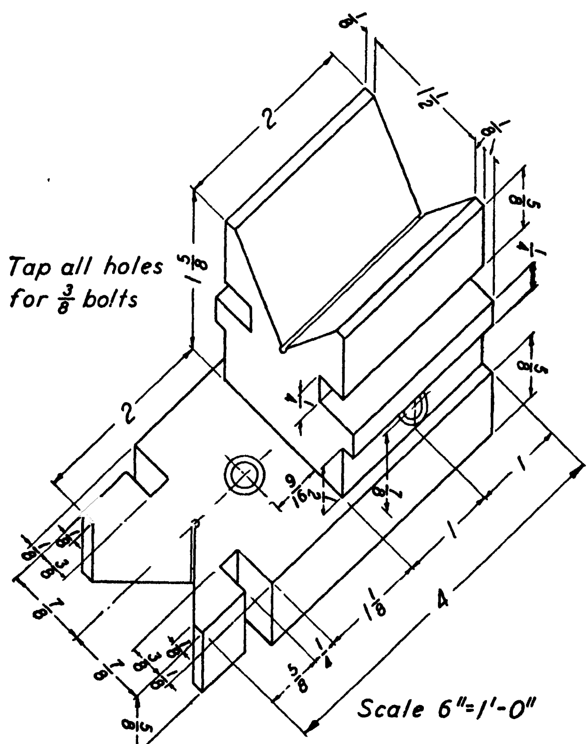


FIG. 6g.—A V block.

Draw and dimension this block, giving front, top, and left side views. Use the face 4″ long and $2\frac{1}{4}$″ in extreme height as the front and make the drawing full size.

Sheet 6-2

This work involves the drawing of various views of an object from a written description. This type of problem brings out the ability to put oral explanations into the form of drawings that is very important in practice. It is required to draw the top view, the front view, and the right side view of a shoe, and to dimension it completely. The scale is $1\frac{1}{2}$″ = 1′-0″.

At the end of a heavy structure, such as a bridge, is often placed a pin—a cylindrical piece of metal. The load on this pin is spread over a rectangular support by means of heavy plates bearing transversely upon the pin; these plates rest upon and are joined to the horizontal base, which is in turn supported by masonry. The structure between pin and masonry is called a "shoe."

A hinged shoe has a base 24″ long north and south, 21″ long east and west, and is 1″ thick. There are four $1\frac{1}{2}$″ holes in it, one at each corner located 2″ from each adjacent edge.

There are two main webs (upright plates) 1″ thick extending north and south, each 5″ in the clear from the center. Each is 24″ wide at the top of the 1″ base and each contains a 5″ diameter hole, central, and 10″ above the top of the base. The webs are roughly triangular in outline and rounded off at the top by radii of 6″, with the centers at the centers of the 5″ holes.

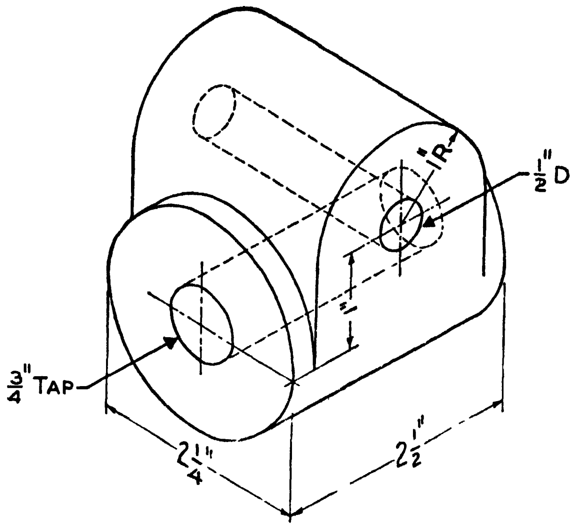
There are three webs running east and west. All are 1″ thick and 7″ high between the two main webs. Outside of the main webs, the cross webs are wedge shaped, decreasing from 7″ high at the main web to nothing at the edge of the plate. One of these cross webs is located in the center of the base running from north to south. The spacing in the clear between the cross webs is 6″; this brings the outside cross webs $4\frac{1}{2}$″ in the clear from the two edges of the plate that run east and west.

Sheet 6-3 (Fig. 6*h*)

This is a cross link such as might be used to connect two axes at right angles to one another. Please draw front, top, and right side views, making the $2\frac{1}{4}$″ circle the front of the object. Drawing is to be made full size.

Sheet 6-4 (Fig. 6*i*)

This is a tool holder whose use is so plain that it needs no explanation. Consider the face which is $4\frac{1}{2}$″ × $2\frac{1}{4}$″ in extreme height to be the front, and draw full size the front, the right side, and the top view. Give all necessary dimensions. It will be found advisable to make the $9\frac{1}{2}$″ space within border lines horizontal, leaving the title box at the left.



SCALE 6" = 1'-0"

Fig. 6h.—A cross link.

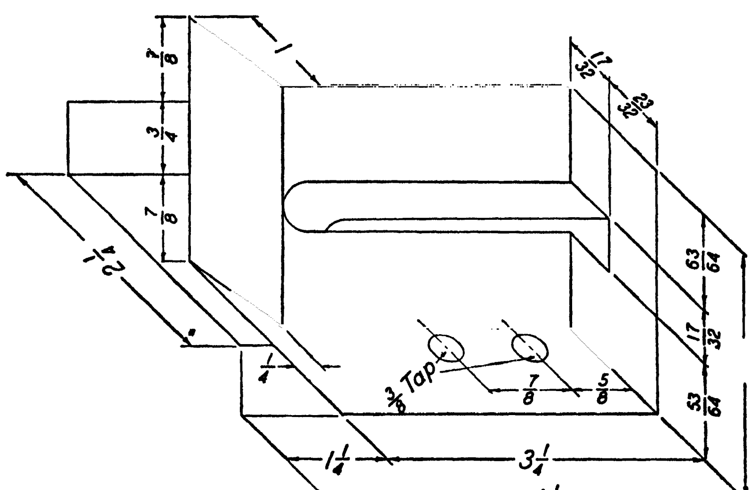


Fig. 6i.—A tool holder.

Sheet 6-5 (Fig. 6j)

This is a diagrammatic arrangement of a series of pipes. As will be noted, the center line of each pipe is shown only by lines and there are no dimensions upon the figure. Copy this as nearly as you can but enlarge to fill your sheet; show the plan or top view, the front view, and the side view. It will be found best if you arrange the length of your sheet horizontally with the title space at the left. Copy the numbers, making them the same

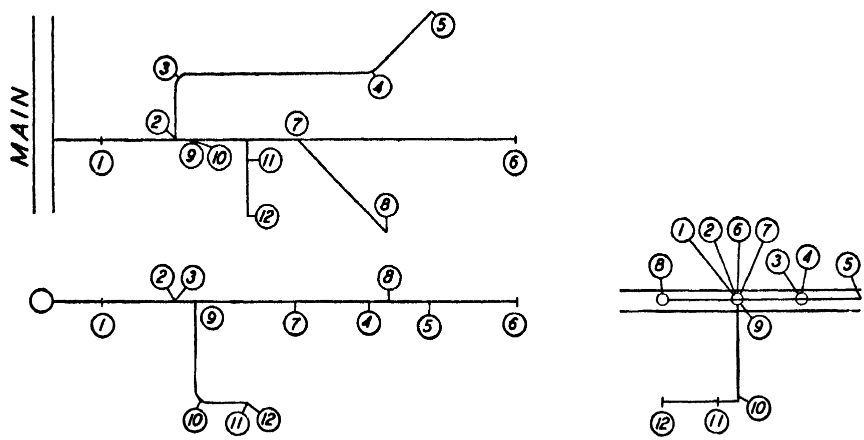


Fig. 6j.—Arrangement of pipes.

as those in the drawing. There is no scale in a diagrammatic drawing and hence no scale should be placed upon it. Letter below each number, and as neatly as possible opposite it, the name of fixture that you would use at the particular location shown. This is a visualization test to determine if you can really see just how these pipes connect. The fixtures used are as follows:

A cap is put on the end of the pipe to stop the flow.

A valve is placed on the pipe to permit the flow to be started, stopped, or regulated.

In a tee, the pipe runs straight through but has another pipe running out at right angles to it.

A Y connection is like a T except the branch is at 45°.

A quarter turn is a 90° bend in the pipe.

An eighth turn changes the direction by 45°.

See how correctly you can interpret this drawing.

This is the end of Lesson 6. Ink work seems quite difficult to a beginner. However, you will be surprised to see how readily the art is mastered in a few exercises.

LESSON 7

SECTIONS

Often it is clearer if a section is used instead of a view. In practice, objects are often very complicated and it is difficult to show clearly the interior construction by means of dotted lines. In many cases both views and sections are necessary in order that the workman and others shall form a correct idea of the object which the draftsman is representing.

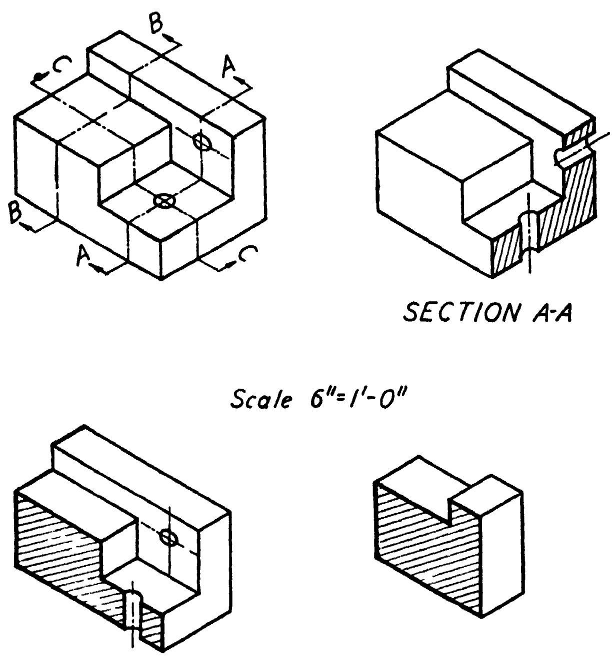


FIG. 7a.—An object sectioned along three planes.

Suppose that we cut through an object, throw one part away, and then look at the other The resulting view is called a *section*. For example, let us consider the simple block shown in Fig. 7*a*. One way of describing the block would be to draw the sections *AA*, *BB*, and *CC*. In Fig. 7*b* are shown the same sections, now made orthographically instead of pictorially as in Fig. 7*a*. In Fig. 7*b*, we have also included the top view, the front view, and

the side view. Not all of these are needed but they are included to make clear to the student the relation between the different views and sections.

If now we cut through the block on the line AA as shown in both figures, throw away the right-hand half and look directly at what is left, we get the section AA as is shown in both drawings. We can proceed similarly for the section BB; note, however, that when the right-hand part is thrown away,

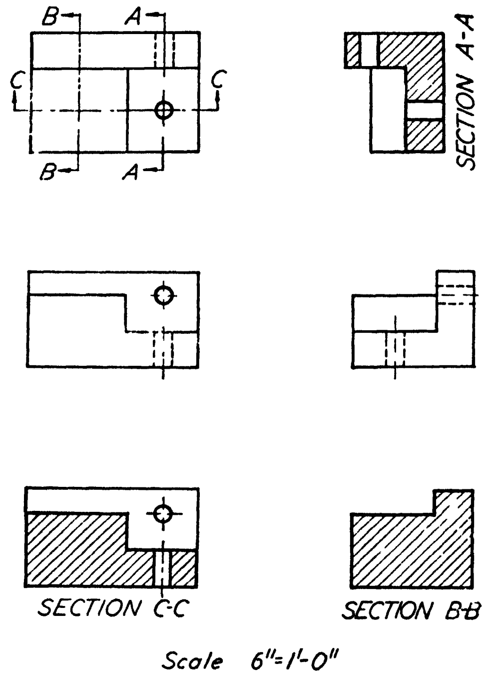


Fig 7b—An object represented by views and sections

what is left is much simpler than in the case of the section AA. Note too that the direction in which we look after one part of the block is thrown away is indicated clearly by the arrows. The section CC is cut in a different direction; we throw away the nearer half and look at the farther half as is shown by the arrows.

The following rules apply to sections:

1. The location of the section must be clearly shown. The line for that purpose as shown in the alphabet of lines, Fig. 6b, is a heavy dash-and-two-dot line.

2. The direction in which we look after the other part is thrown away should be indicated by arrows located at the end of the cutting line.

3. Underneath each section should be marked the name of the section. Usually capital letters are employed. Do not repeat these letters on a single sheet but make a different letter for each different section.

4. Rules 1, 2, and 3 are frequently disregarded when the men who use these drawings will understand just where the section is taken, or where there cannot be any possible confusion about the place where the section is cut.

5. The laws of direction and opposition should be followed. That is, we look from the place where the section is drawn, toward the point where the section is located; it is desirable to put it so that each point of the section is directly opposite the same point in the view in which the location of the section is shown.

6. Dotted lines are often omitted if they do not assist one in understanding the section.

7. The portion actually cut is emphasized in some way. The usual method is cross-hatching as shown in Figs. *7a* and *7b*. Sometimes the cut surface is clouded by using the side of a pencil until it is thoroughly smeared. Such a procedure shows up clearly in a drawing and takes nicely in a blue print. Sometimes it is tinted but many papers will not take the water that is used in this process. Small thin sections are often blackened with pencil or ink.

8. The usual angle of the cross-hatching is 45° with the horizontal in either direction. Skew objects look better if the angle of 45° is with one main side of the object.

9. If the section cuts through several pieces, adjacent parts should be cross-hatched in opposite directions. Many concerns vary the cross-hatching with the material that is cut. Typical conventional signs of this kind are shown in Fig. *8f*.

10. Sections parallel to the axis of long thin members are usually left unsectioned. Thus a section along the axis of a shaft, a rivet, a bolt, a gusset plate, or a spoke or similar object is usually shown as a view.

The sheet for this lesson will be drawn in ink for the first time. Students should review very carefully the instructions about inking in Lesson 6 before undertaking this work.

REQUIRED WORK: LESSON 7

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

7-1. What is meant by cross-hatching?

7-2. How is the position of the section indicated?

7-3. When should dotted lines be shown in a section?

7-4. How may sections of small thin objects be represented?

Sheet 7-2 (Fig. *7d*)

7-5. What is the size of the drilled hole in these two hose connectors?

7-6. State the diameter of the tapped holes.

7-7. What is the overall height of the hose connector shown in the upper part of the cut?

7-8. Name the three outside dimensions of the lower hose connector.

Sheet 7-3 (Fig. 7*e*)

7-9. What is the length shown for the typical terra-cotta blocks?

7-10. State the top and the bottom widths of the key for arches in the terra-cotta blocks.

7-11. What is the length of the typical concrete blocks measured in a direction parallel with the voids?

7-12. State the extreme length and width of the vacant spaces in the larger of the two concrete blocks.

Sheet 7-4 (Fig 7*f*)

7-13. State the diameter of the hand wheel of the gate valve.

7-14. How many circular openings are there in the rim of the wheel?

7-15. What is the length of the spindle?

7-16. How many parts are there in this valve?

Sketch the following sections:

7-17. One across the width of the monument in Fig. 4*h*.

7-18 A horizontal section halfway up in the post of Fig. 4*i*.

7-19. A vertical section through the middle of the 4½" length in Fig. 6*i*.

7-20. A vertical section in Fig. [illegible] across the middle of the upper V.

LETTERING

For the student's convenience, we have here repeated Fig. 1*d* as Fig. 7*c*. Copy these seven characters in ink, first vertically and then inclined, ¼"

Fig. 7*c*.

high, 3/16" high, and ⅛" high. Be sure to rule the proper guide lines and to make the letters the required height; above all else, the letters must be exactly the same height in a given row. Beginners will find it advantageous to work the lettering in pencil first; experienced men work directly in ink and students should gradually accustom themselves to this procedure.

SHEETS

All sheets are to be finished in ink on detail paper. Draw first in pencil, making lines only heavy enough so that one can see them to do the inking.

Sheet 7-1

This should be undertaken only by those interested in structural work and only when a handbook is available to give sizes of items mentioned.

A column rests directly on three 24″ I's weighing 79.9 lb. per linear foot, 7′-8″ long, and spaced 9″ center to center. These in turn rest on eight 8″ I's weighing 35 lb. per linear foot, 7′-6″ long, and spaced 12″ apart. The whole is encased in concrete, the protection to the foundation steel being 2 to 3″ of this concrete.

Draw plan, a section parallel to the 24″ I-beams, and a section parallel to the 8″ beams. It is customary in cases like this to pass the section through the concrete, but to show the I-beam nearby as though visible. The scale is ½″ = 1′-0″. Dimension as for structural engineering.

Sheet 7-2 (Fig. 7*d*)

These drawings represent pictorially two hose connectors used to support the piping system in the body of an automobile. Draw and dimension

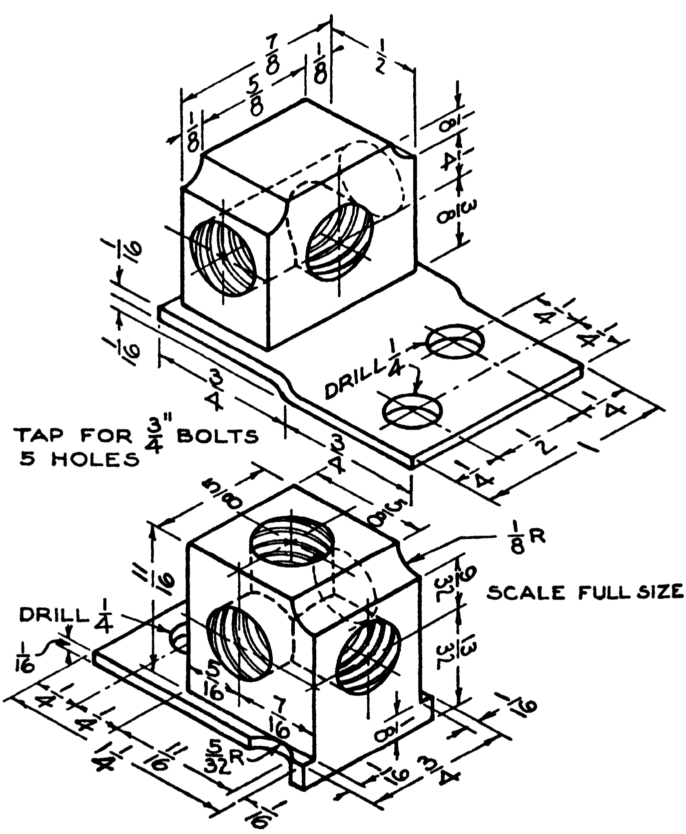


Fig. 7*d*.—Hose connectors for an automobile.

both, giving each top view. In addition, for the upper hose connector, show a section through the middle of the 1″ dimension and also at right angles to it through the middle of the 3/8″ tapped hole. For the second, in addition to the top view, give a vertical section through the middle of the 3/4″ dimension and also a vertical section perpendicular to the first named through the center of the 3/8″ tapped hole.

Sheet 7-3 (Fig. 7e)

This figure shows typical terra-cotta blocks and concrete blocks as used in building construction. The scale of the cut is 3/4″ = 1′-0″. Copy it double size and mark the scale of 1 1/2″ = 1′-0″ on the drawing.

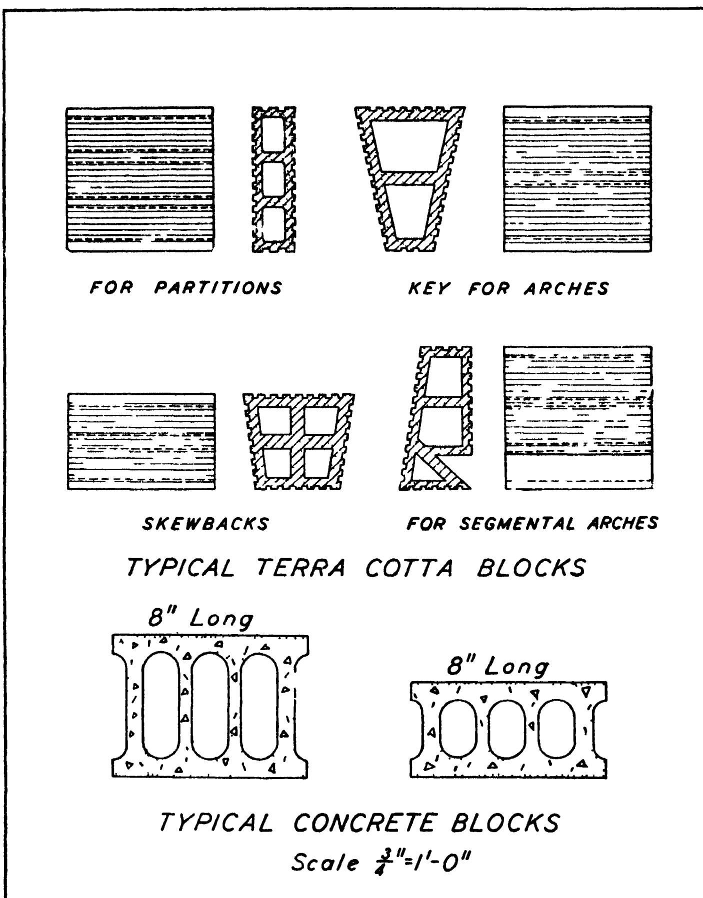


Fig. 7e.

SHEET 7-4 (Fig. 7f)

This is a section of a gate valve which is used to control the flow of water through a pipe. It is shown as a single section through the center

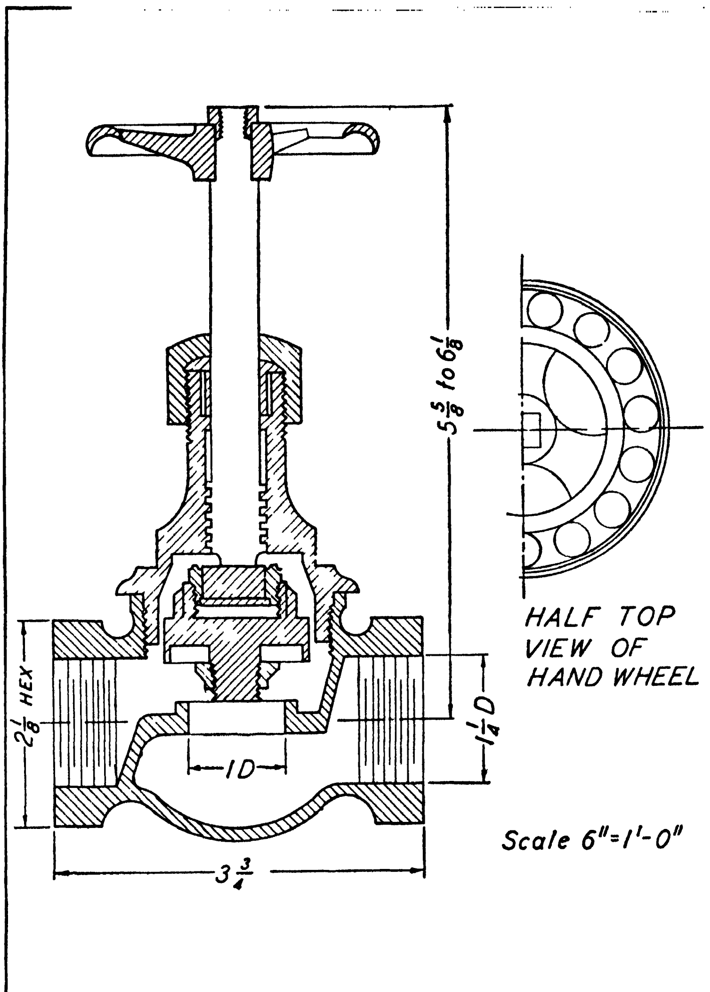


FIG. 7f—A gate valve

line of the pipe, at a scale of 6″ = 1′-0″. Copy this, making it double size or 12″ = 1′-0″. Notice the spindle, a long longitudinal object, is not sectioned. Give the main dimensions of the object as they are shown in the cut.

SHEET 7-5

This is an original problem in design and should be undertaken only by students who possess a certain amount of ability.

Design an eating table for a camp to accommodate eight men. Show at a scale of $\frac{1}{2}'' = 1'\text{-}0''$ the plan, the front view, and a section taken transversely to the length of the table. Insert a bill of materials. This is a tabulation which states first a certain letter which appears upon the drawing, showing where the material is used. Then should come the number of pieces; next the description of the pieces; sizes; and finally the lengths. A slightly different bill of material is seen in Fig. 18*j*.

We have now reached the end of Lesson 7; we hope that you are able to visualize sections as well as the ordinary views used in describing objects.

LESSON 8

SPECIAL SECTIONS

The cutting plane of the section is not necessarily straight or a single plane. For example, in Fig. 8*a* is shown a top and front view of an irregular block. In the top view, the location of the section *AA* is shown, following

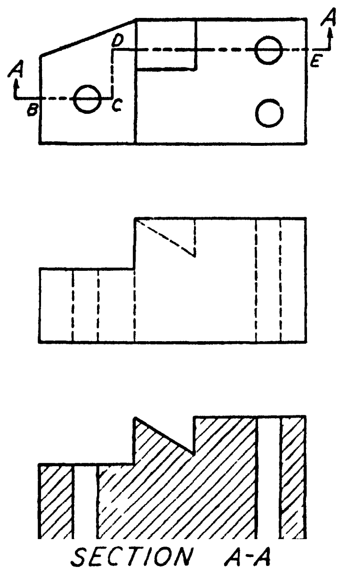


FIG. 8*a*.—An irregular section.

the irregular line *BCDE*. In the lower part of the cut is shown the section *AA* itself. Note that the section from *B* to *C* and from *D* to *E* is shown, and that the portion *CD* is omitted entirely.

Sometimes a section may be curved. In such a case, it is impossible to follow out the law of opposition as only one point, preferably the starting point, can be placed opposite its position in the view in which the section is taken.

In Fig. 8*b* are shown various sections, some of which will serve as a review for ordinary sections. Special attention is called, however, to the sections at the right marked "partial section." In the extreme right-hand cut, one half is a right side view and the other half is a section along the line *A*. Next to it is another composite drawing. Part of it to the left is an

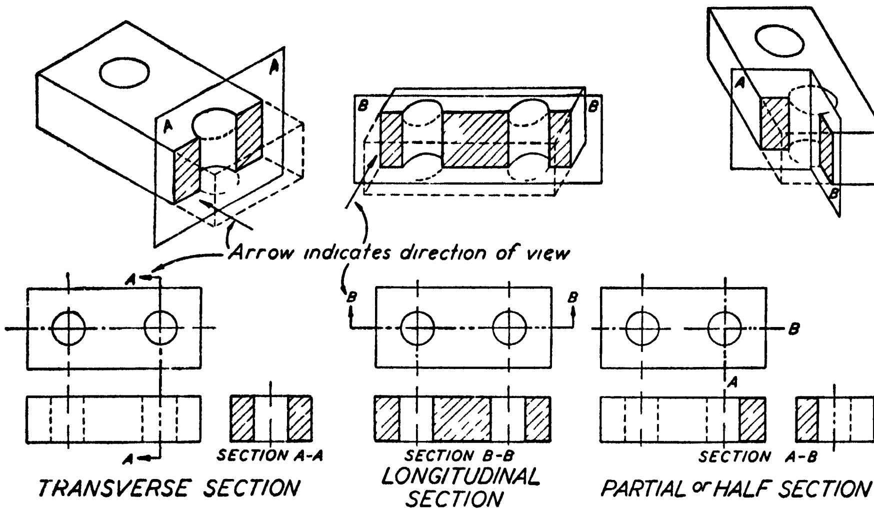


FIG. 8b.

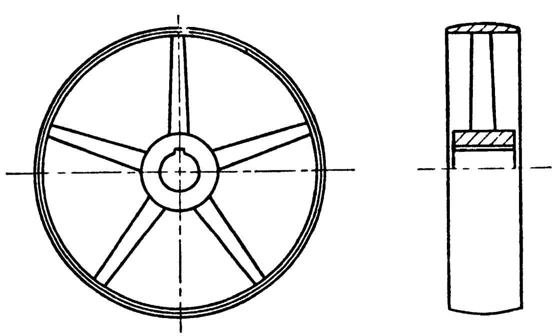


FIG. 8c.—A pulley with a front view, a half side view and a half section.

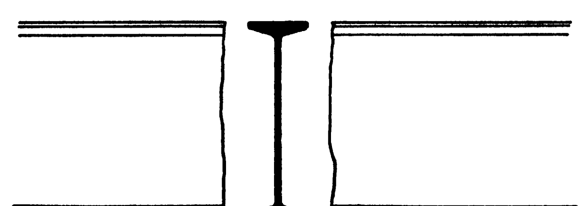


FIG. 8d.—A revolved section.

ordinary view, and a small portion at the right is a section along the line *B* as marked in the view above. A special case of this, employed in the representation of pulleys, flywheels, and so forth, is shown in Fig. 8*c*.

REVOLVED SECTIONS

Occasionally, as in Fig. 8*d*, a view is broken and the section is inserted in the middle of the object. Sometimes, as is shown in the cut, the member is broken for the insertion of the section; again the lines of the view run straight through. Both methods are fairly common. Where the section is constant, the revolved section may be dimensioned to advantage. However, it is occasionally employed to show general shape even where the cross section varies; in such cases, the dimensions must be placed elsewhere. The general practice in structural work is to show only two lines for each flange although there are really three, as in the cut.

REQUIRED WORK: LESSON 8

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

8-1. Explain fully the revolved section.
8-2. Is it allowable to use a curved section?
8-3. What is meant by a broken section?
8-4. Explain the partial section.

SHEET 8-1 (Fig. 8*f*)

Describe the conventional signs for the following materials:

8-5. Cast iron.
8-6. Asbestos.
8-7. Copper.
8-8. Fire brick.
8-9. Brick (in section).
8-10. Brick (in outside view).
8-11. Babbitt.
8-12. Glass.

SHEET 8-5 (Fig. 8*h*)

8-13. How many teeth are there in the gear?
8-14. What is the angle at which the small end of the shaft is tapered off?
8-15. State the pitch diameter of the clutch.
8-16. How many splines are there on the shaft?

Sketch the following:

8-17. A horizontal section through the middle of Fig. 4*d*, considering the upper drawing to be a top view.
8-18. A horizontal section through the middle of Fig. 5*b*.
8-19. A vertical section through the middle of the steps of Fig. 5*j*.
8-20. A section through the middle of the 3½″ dimension of Fig. 5*k*.

LETTERING

Copy in ink the letters *D, P, R, B, J, U,* as shown vertically and inclined in Fig. 8*e* repeated from Fig. 2*d*. Make each in letters ¼″ high, $\frac{3}{16}$″ high, and ⅛″ high.

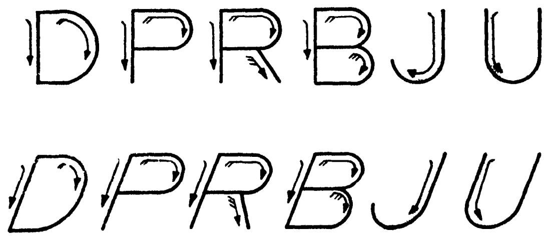


FIG. 8*e*.

SHEETS

All drawings are to be made in ink upon detail paper.

SHEET 8-1 (Fig. 8*f*)

Copy these conventional signs, making the squares and in general the signs themselves just twice as large as those shown in the cut. Underneath neatly letter the name of the material which is represented.

SHEET 8-2

This plate, differing radically from the preceding, calls for designing skill.

Design a jig for boring five half-inch holes always in a fixed position with reference to one another. There are four holes 4″ apart in one direction and 6″ apart in the other, and exactly in the middle is the fifth hole. They are to be centered in a space 8″ × 9″, the 4- and the 8-inch dimensions being parallel. It would seem fairly simple to put in the half-inch holes at the required distances apart. However, the continued drilling through this plate, if made of ordinary materials, would in time enlarge the holes so that they would no longer be exact. Hence, we will make the holes 1″ in diameter and provide a bushing of hardened steel with a half-inch hole which fits exactly in the 1″ holes.

Design and dimension this jig with its five bushings. A top view of the plate at a scale of 6″ = 1′-0″ will be sufficient if its thickness is given. For the bushings, give a top view and a section through the axis of the same, at a scale of 12″ = 1′-0″. This drawing is to be dimensioned. It is not necessary for us to give full information, as it is desired to accustom you gradually to the use of your own judgment in deciding certain minor matters.

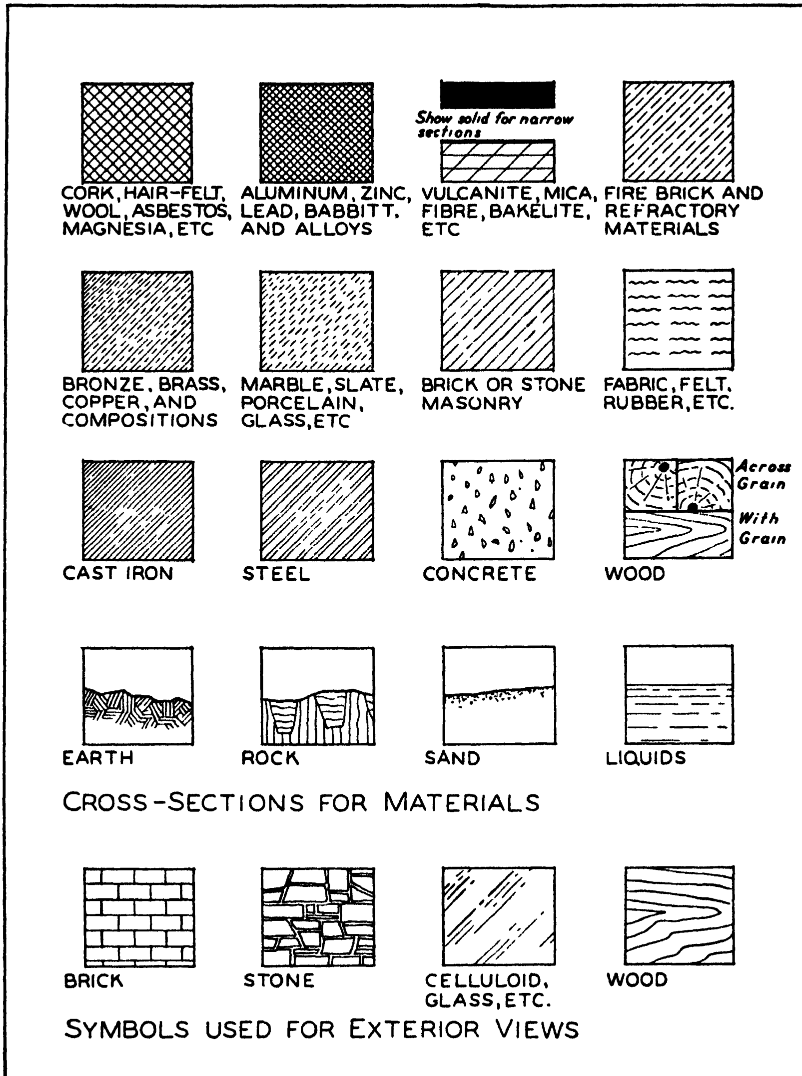

Show solid for narrow sections
CORK, HAIR-FELT, WOOL, ASBESTOS, MAGNESIA, ETC
ALUMINUM, ZINC, LEAD, BABBITT. AND ALLOYS
VULCANITE, MICA, FIBRE, BAKELITE, ETC
FIRE BRICK AND REFRACTORY MATERIALS
BRONZE, BRASS, COPPER, AND COMPOSITIONS
MARBLE, SLATE, PORCELAIN, GLASS, ETC
BRICK OR STONE MASONRY
FABRIC, FELT, RUBBER, ETC.
CAST IRON
STEEL
CONCRETE
Across Grain
With Grain
WOOD
EARTH
ROCK
SAND
LIQUIDS
CROSS-SECTIONS FOR MATERIALS
BRICK
STONE
CELLULOID, GLASS, ETC.
WOOD
SYMBOLS USED FOR EXTERIOR VIEWS

Fig. 8*f*.

Sheet 8-3

A flywheel is 24″ in diameter. It has a rim 4″ wide and 2″ in full depth and is gradually curved to have a total depth of 1¼″. The wheel has at its center a 3″ diameter hole with a ⅜″ × ¾″ slot for the key with a hub 5¾″ in diameter by 5″ long. There are 5 elliptical arms 2¼″ × 1⅛″ at the rim and 3″ × 1½″ at the hub. Draw a half front view and a combined half view and half section at a scale of 1½″ = 1′-0″. Dimension fully.

A flange coupling is 7″ in diameter and has a hole for a shaft 1⅛″ in diameter with a ⅛″ × 1/16″ slot for the key. The hub is 2½″ diameter by 4½″ long. The bolt circle (the circle passing through the centers of the bolts) is 4½″ in diameter, and it has 6 hexagonal-headed bolts with hexagonal nuts. The coupling is made in two parts; each flange is 1⅛″ wide and each web is ⅝″ thick. Depth of the flange is ¼″. Draw and dimension fully, at a scale of 6″ = 1′-0″, a one-half front view and a combined half side view and half section.

Sheet 8-4

Both drawings on this sheet are made at a scale of 1½″ = 1′-0″ and there is to be a half front view and a combined half view and half section of each object. Both are to be dimensioned fully.

The gear wheel has an outside diameter of 25½″, a pitch diameter of 24″, and a root diameter 22¼″. The inside diameter of the flange is 18″,

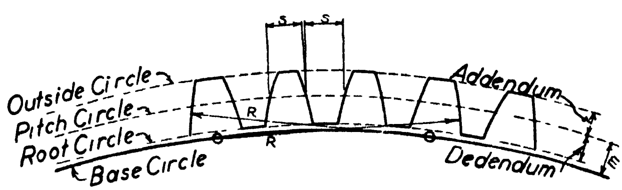


Fig. 8g.—A portion of a gear wheel.

the hole for the shaft is 4″ in diameter, and it is provided with a 1″ × ½″ slot for the key. The hub is 7⅝″ in diameter and 7″ long; it is unsymmetrical, 4″ on one side and 3″ on the other. There are 4 arms, elliptical in section, 1½″ × 3″ at the rim and 2″ × 4″ at the hub. There are 32 teeth on this wheel; the draftsman should receive special instruction as to how they should be drawn. Sometimes, they are not shown at all but the number of teeth is merely lettered upon the drawing. Often only one tooth is drawn and the number is indicated. They may be merely sketched in, or, again, they may be thoroughly worked out and drawn in. We wish to emphasize that the exact determination of gear teeth is an important matter

for which we cannot spare the proper space at this point. However, gear teeth may be laid out as is stated below. It must be understood that the method is diagrammatic. We will assume that the number of gear teeth N is given and the mean diameter of the wheel, D, is stated in inches. Then the results below are all in inches.

$$\left.\begin{aligned} S &= \frac{\pi D}{2N}, \\ \text{Addendum} &= \frac{D}{N}, \\ \text{Dedendum} &= \frac{7}{6}\frac{D}{N}, \\ m &= \frac{D}{60}, \\ R &= \frac{D}{8} \end{aligned}\right\} \quad \text{See Fig. } 8g$$

For example, let the gear be 20″ in diameter and have 80 teeth. Then we may compute that the spacing S is 0.39″, the addendum is 0.25″, the dedendum is 0.29″, m is 0.33″, and R is 2½″.

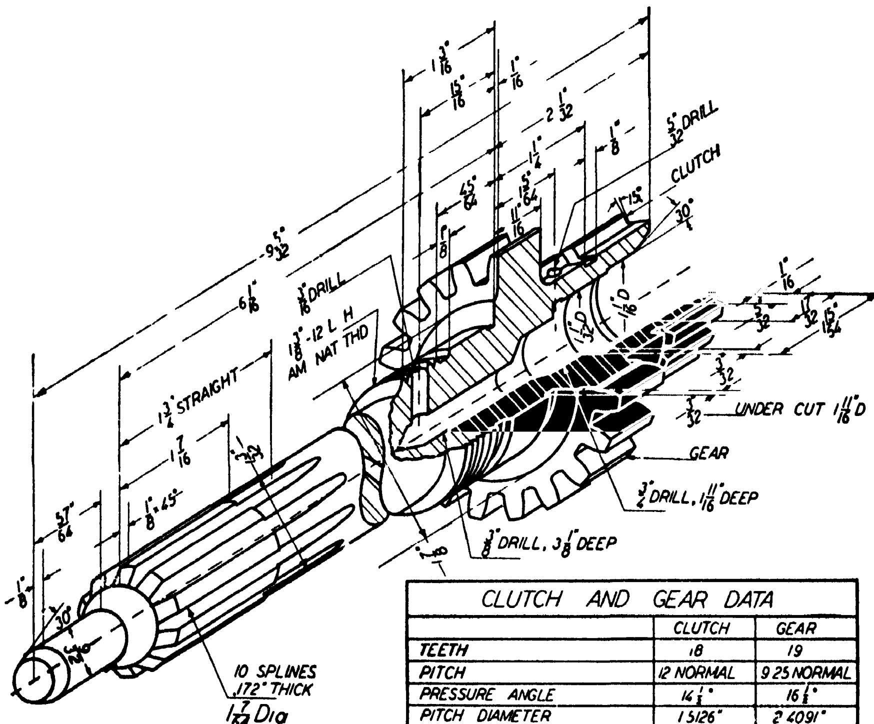
As an approximate rule which is only roughly correct, we will suggest that the teeth be drawn in as indicated in Fig. 8g. As is there shown, make the spaces between the teeth equal to the thickness of the teeth themselves on the pitch circle and use a radius of ⅛ of the diameter in drawing the sides of the teeth.

The pulley is 24″ in diameter and has a 3″ diameter hole for the shaft with a ⅜″ × ¾″ recess for the key. The hub is 5¾″ diameter by 5″ long. There are six arms having an elliptical section, 1⅛″ × 2¼″ at the rim and 1½″ × 3″ at the hub. The rim is ⅝″ thick at the center but its surface is "coned" (rounded) to a radius of 24″, making it a bit thinner at the edges of the rim. Coning helps to keep the belt on the wheel.

SHEET 8-5 (Fig. 8h)

Draw and dimension full size the clutch and gear shown in Fig. 8h. A front view with a partial section at the right-hand end will do here. Copy the table, giving clutch and gear data, as it is necessary in order to fully understand the making of the parts mentioned. This is a part of the change gear for an automobile.

This is the end of Lesson 8. It is suggested that a written review lasting an entire exercise be held at the next meeting of the class. Whether such a quiz is given or not, this is the time to go over the past work and be sure that you understand it.



CLUTCH AND GEAR DATA		
	CLUTCH	GEAR
TEETH	18	19
PITCH	12 NORMAL	9 25 NORMAL
PRESSURE ANGLE	14 1/2°	16 1/2°
PITCH DIAMETER	1 5126"	2 4091"
ADDENDUM	.1002"	1613"
FULL DEPTH	1325"	275"
CIRC TOOTH THICKNESS	172"- 174"	1995"

Fig. 8h.

LESSON 9

SYMMETRY

A knowledge of symmetry is essential in the making or the reading of drawings.

An object is said to be symmetrical about a surface when every point on the object on one side of that surface has a corresponding point exactly opposite on the other side of the surface and exactly the same distance from the surface but in an opposite direction. For example, the exterior frame of a man is symmetrical about a plane passed through his nose and between his legs. His hands, if at rest, will have the same dimensions; each point upon the right hand will be the same distance from the central plane as is the corresponding point on the left hand. Internally, a man is not symmetrical; for one thing, he has a heart on his left side and a liver on his right.

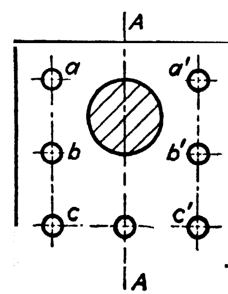


FIG. 9*a*.

This same idea is used in making the individual views of an object. A view is said to be symmetrical about a line when every point on one side of that line has a corresponding point on the other side of the line the same distance away but in the opposite direction. Thus, in Fig. 9*a*, the plate shown is symmetrical about the line AA, drawn through the center line of the area. Two holes that are intersected are symmetrical with respect to AA; a and a', b and b', and c and c' are likewise symmetrical; similarly, each point on one side has a corresponding point on the other side symmetrical with it.

The principal advantage of symmetry is that only one-half of a symmetrical object need be shown and dimensioned; for the remainder, either of the following notes is enough:

Symmetrical about the line . . .

or Sym. abt. this ℄

In Fig. 9*b* are shown a front view and a section of a symmetrical two-family house.

The first object in Fig. 9*c*, a plain shaft, is symmetrical about any plane perpendicular to its axis at its midpoint, and also about any plane through its axis. The second object is symmetrical only about the latter. The third

shaft has only one plane of symmetry, and this passes through the middle of the key seat. The two wrenches are symmetrical about a center line between them. Apparently they are right and left as mentioned in the next

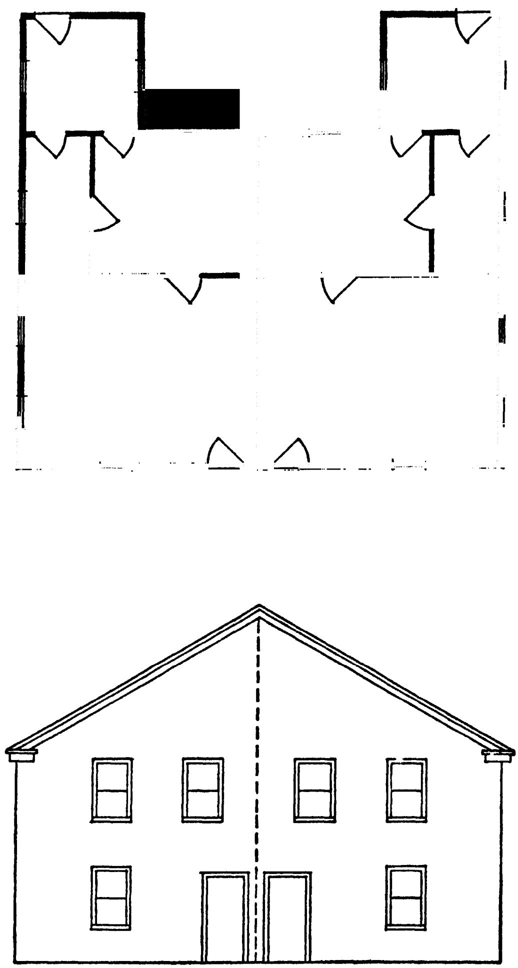


FIG. 9b —A symmetrical dwelling.

lesson. However, they will be alike if symmetrical about a plane in the middle of their thickness.

When you are given a drawing to be made, there are two questions to be considered:

Is it symmetrical?

If it is symmetrical, will the time and space saved by drawing only one half be enough to overcome the greater difficulty in understanding it?

The usual answer is "yes" unless the object is not simple.

Sometimes an object is symmetrical except for some small item. For example, an ordinary bridge is often symmetrical except that it has round

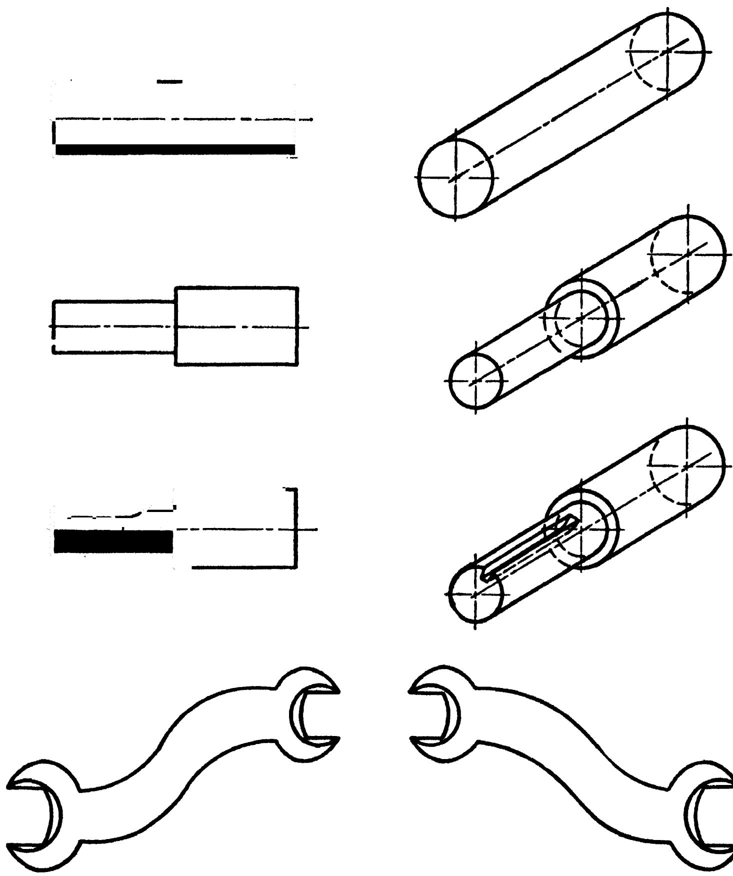


FIG. 9c.

holes for foundation bolts at one end and slotted holes at the other end to provide for expansion. In such cases, it is customary to mark the center line:

Symmetrical about this center line except as noted.

Then where the holes are shown, there will be lettered:

$1\frac{5}{16}''$ round holes this end.

$1\frac{5}{16}'' \times 2''$ slotted holes far end.

TRACING CLOTH

In some respect, this is like vellum. It must be fastened down at four corners and the cloth is ruined by folding or by moisture in any form. There are differences as well. The material will not tear if it is properly handled. The two surfaces of the tracing cloth are quite different; on the glossy side, a pencil mark scarcely shows, while it is very plain on the rough side. We will work on the rough side; consequently the shiny side should be placed toward the drawing board.

The tracing should be powdered after it is fastened down. Prepared talc powder or borated talcum powder may be employed. Students generally use ordinary chalk. Mark thoroughly a space about a foot square and clean the board with a blackboard eraser; then use the same eraser to apply the chalk powder over the entire drawing. Dust off with a clean rag; excess particles are likely to cause blots.

Erasures are made on tracing cloth much as on detail paper.

The drawing is usually made first in pencil on detail paper and then copied in ink on tracing cloth. In practice, many draftsmen work directly on the cloth. Some lines are drawn in pencil and as many as possible directly in ink. Dimensioning and lettering are usually done without any penciling work at all. It is advantageous here to use guide lines on a separate sheet, moved underneath each bit of lettering that is to be done.

EXAMPLES

The upper hose connector shown in Fig. 7*d* has no axis of symmetry. The lower hose connector is symmetrical about a vertical plane cutting the middle of the 3/4″ dimension. Of the blocks shown in Fig. 7*e*, all are symmetrical about a plane passed in the middle of their length. Every section except the skew back has another axis of symmetry, and the sections of the typical concrete block have two other axes.

REQUIRED WORK: LESSON 9

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

9-1. Define symmetry.

9-2. Name the vertical capital letters which are symmetrical about only one center line.

9-3. What vertical capital letters are symmetrical about two center lines?

9-4. State the vertical capital letters that have no axis of symmetry.

In the following twelve questions, the drawing of an object will be named and you will be asked to state whether the object itself is symmetrical or not. In case it is

symmetrical, state every axis about which it is symmetrical; in case it has no axis of symmetry, say "unsymmetrical."

9-5. Lot plan, Fig. 1*e*.
9-6. Roof truss, Fig. 1*h*.
9-7. Bridge truss, Fig. 1*h*.
9-8. Athletic field, Fig. 1*i*.
9-9. Pump handle, Fig. 2*g*.
9-10. Cotter pin, Fig. 3*g*.
9-11. Valve, Fig. 3*h*
9-12. Gib head key, Fig. 4*g*.
9-13. Monument, Fig. 4*h*.
9-14. Bearing, Fig. 4*h*.
9-15. Post, Fig. 4*i*.
9-16. Steps, Fig. 5*j*.

Sketches

The following objects are symmetrical. Sketch one-half of a view that has symmetry.

9-17. The dog, Fig. 5*m*.
9-18. The jig, Fig. 5*k*.
9-19. The V block, Fig. 6*g*.
9-20. The cross link, Fig. 6*h*.

LETTERING

Copy in ink the letters A, E, F, H, I, K, L, M, N, T, V, W, X, Y, Z, shown in the vertical and the inclined form in Fig. 9*d*. Make each in letters ¼″ high, 3⁄16″ high, and ⅛″ high.

FIG. 9*d*.

SHEETS

The objects suggested for drawing in this lesson are either symmetrical or symmetrical except for obvious differences. In practice, some of these would be drawn with a line of symmetry and the omission of part of the object. However, symmetry may be made to pay only for larger objects such as are beyond the reach of a single lesson in this course.

All drawings are to be made in ink upon tracing cloth.

Sheet 9-1 (Fig. 9*e*)

We have shown here in Fig. 9*c* at a scale of 3″ = 1′-0″, a half front and half side view and a quarter top view of a support for a grinder wheel. You

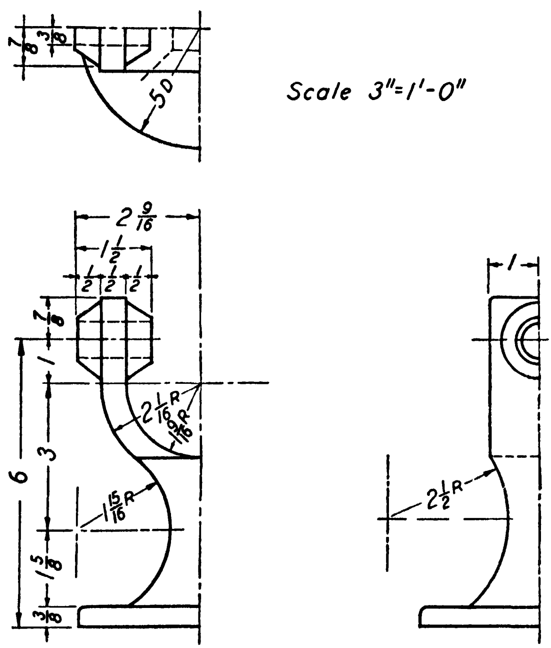


Fig 9*e* —Part of a grinder wheel support.

are to complete the views showing each at a scale of 6″ = 1′-0″. Dimension completely but remember that a dimension on a half of a symmetrical object shown as symmetrical is usually considered to be enough.

Sheet 9-2 (Fig. 9*f* and Fig. 9*g*)

Pictorial dimensioned drawings of a part of a caster are shown in Figs. 9*f* and 9*g*. Please draw and dimension front and side views of each object at a scale of 6″ = 1′-0″.

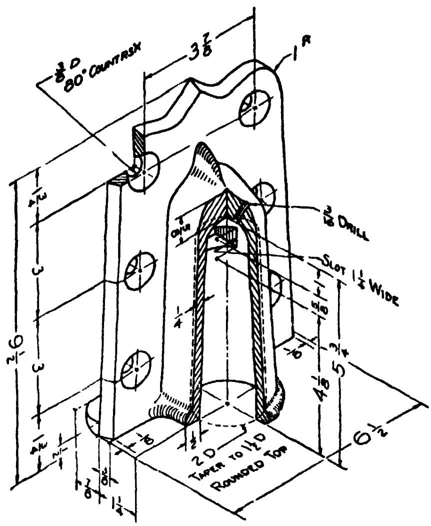


FIG. 9f.—Part of a caster.

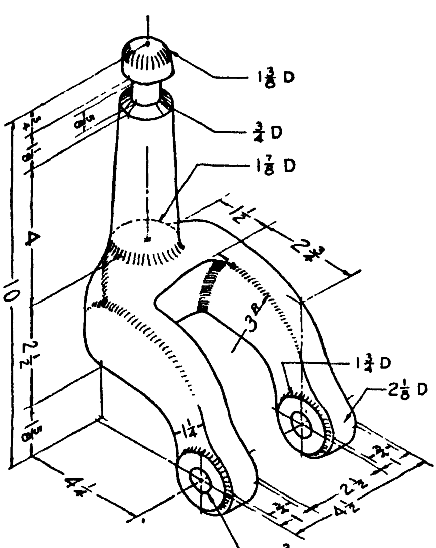


FIG. 9g.—Part of a caster.

SHEET 9-3 (Fig. 9*h*)

In Fig. 9*h* is shown a front elevation of a fireplace with a vertical section and also a horizontal section through it. The scale of the cut is $\frac{1}{4}'' = 1'\text{-}0''$. Please draw this fireplace at a scale of $\frac{1}{2}'' = 1'\text{-}0''$. It is customary in

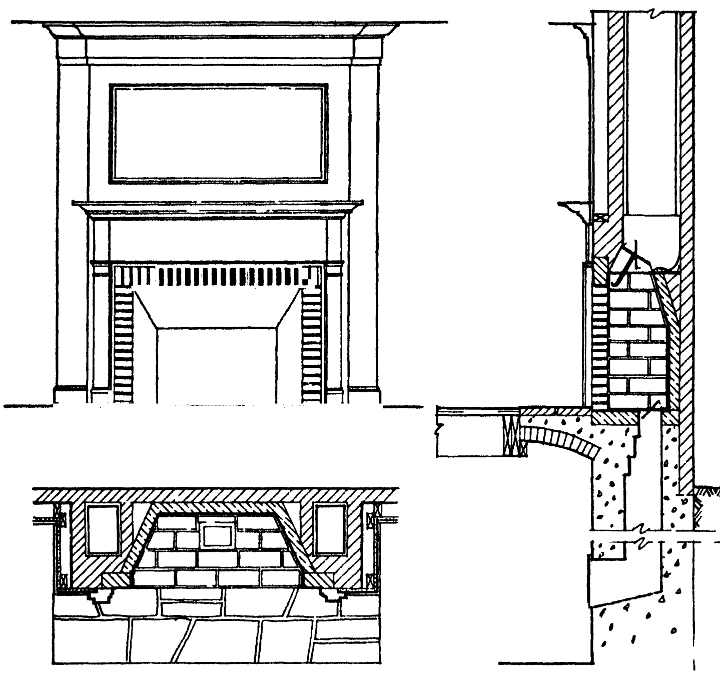


FIG 9*h* - A fireplace

work of this kind to make the drawing very carefully to scale as the contractor works to scale in building it. As it will not have to fit in with any other object except those immediately around the fireplace, this practice causes no difficulty and is generally followed.

SHEET 9-4 (Fig. 9*i*)

In Fig. 9*i* is shown the pictorial dimensioned drawing of a piston for an automobile. Please describe this object completely by full size views and sections with dimensions. Make first a half view and a half section looking squarely at the $\frac{31}{32}''$ diameter hole. Beneath, make a bottom view of this piston. At the side make a section at right angles to the direction of the first-named view, and below in the left-hand corner make a quarter section through these $\frac{31}{32}''$ diameter holes.

This work is fairly difficult and should be undertaken only by those who are interested in mechanical work and particularly in the construction of an automobile.

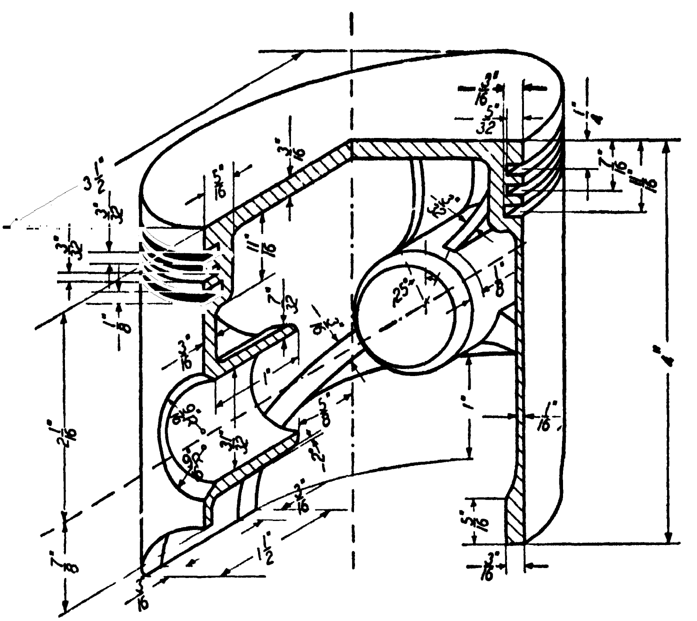


Fig. 91.—A piston for an automobile.

Sheet 9-5 (Fig. 9j)

In Fig. 9j are shown the pictorial drawings of three parts of a grinder guard with dimensions. Please describe each by suitable drawings at a scale of ½″ = 1″.

This is the end of Lesson 9.

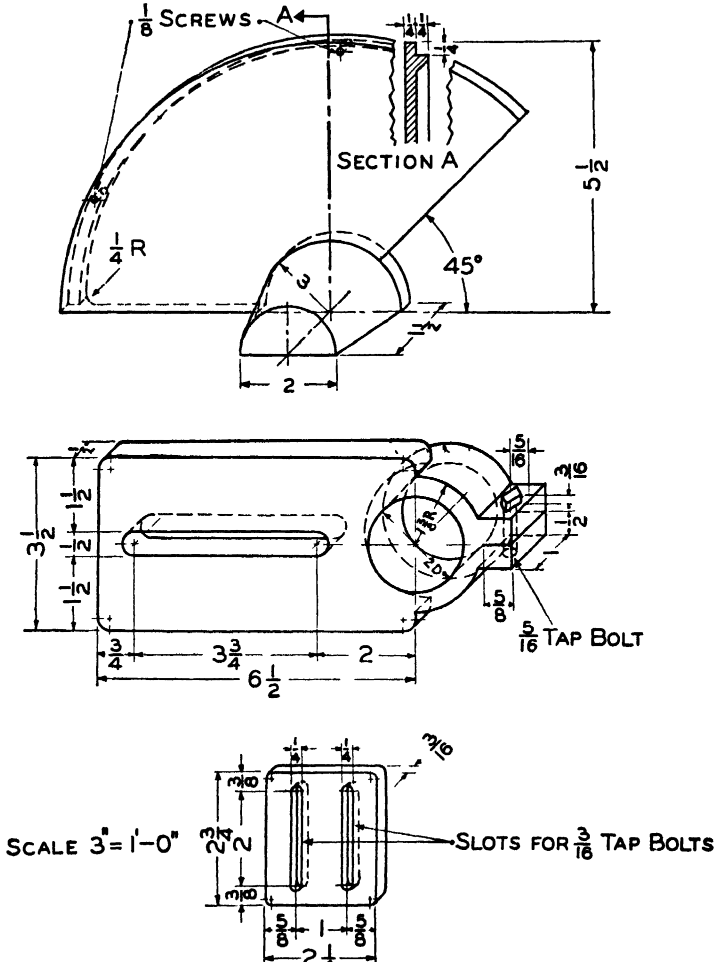


FIG. 9j.—Parts of a grinder guard.

LESSON 10

REVERSALS OR RIGHTS AND LEFTS

In industrial work it is often necessary to build an object in two forms, each reversed from the other. Competent men in industry must be able to make one form from the other or to make them both from a single drawing.

Consider the object A as shown in Fig. 10a; it is not symmetrical about any axis. Now, suppose a plane M to be erected on one side of A and then an object, A', made symmetrical about M with A. That is, a' is opposite

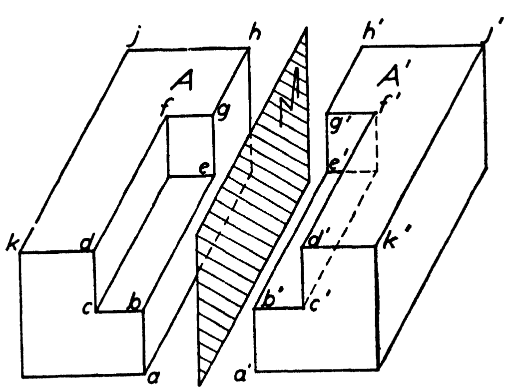


FIG. 10a.

a and both are the same distance from the plane M. Similarly, b and b', c and c', d and d', and so forth, are symmetrical about M. In the drafting room and the workshop, the one shown in the drawing is called the ***right;*** the one that we must create in our minds is termed the ***left.*** Thus, in the above figure, A might be shown; then in practice it would be called the right, while A' would not be shown but would be called for as a left of A.

If, about any plane as an axis, we construct an object symmetrical with a given object, the given object is called a right and the constructed object, a left. The position of the plane chosen as an axis does not make any difference in the result; the same left will be obtained for any position of the plane M.

Some engineers say: Place the object before a mirror; then the object itself is a right while its mirror image is the left. This is quite correct; this

method gives the same results as the use of a plane of symmetry. Often you can check your answers by the use of a looking glass.

The necessary views for the right of the object should be marked about as follows:

8 BLOCKS REQUIRED	4 AS SHOWN, MARK B6^R
	4 OTHER HAND, MARK B6^L

However, this information is often shortened, as rights and lefts are used a great deal and the mechanics do not need such detailed instructions. For example, the following form would be understood everywhere:

8 BLOCKS	4 B6^R
	4 B6^L

The following truths will help the mechanic in his work; in many cases, he will be able to see the reason for the statements as given:

I. If a piece is symmetrical about any axis, the right and the left are the same; that is, there is neither right nor left.

II. If a large piece is symmetrical, the small pieces of which it is composed are opposite hands (right and left) on different sides of the center line.

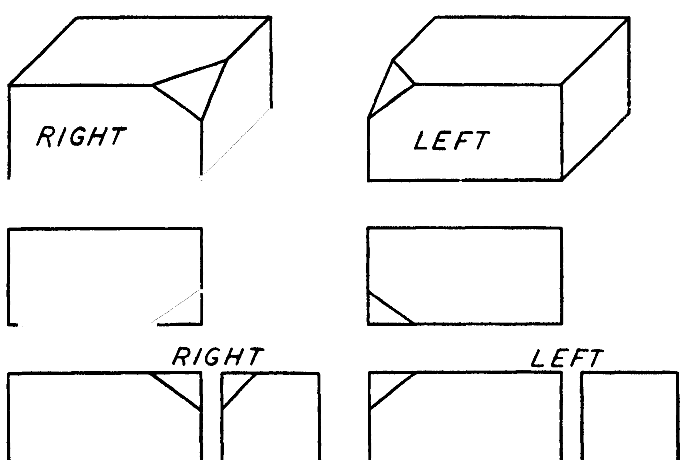


FIG. 10*b*.—Two blocks which are right and left.

That is, of two similar parts, symmetrically situated in a symmetrical object, one is a right and the other is a left. However, if the small part is symmetrical about its center line, its right and left are the same and no distinction need be made upon the drawing.

III. When large pieces are right and left, the pieces of which a left of the large piece is composed are lefts of the corresponding parts in the rights of the large piece. That is, a small part which is a right in the large right piece is a left in the large left piece; also, a left portion in the large right piece becomes a right in the large left piece. This rule is modified by the first principle: if the small piece is symmetrical about any axis, its right and left are the same; for such cases, right and left are not mentioned on the drawing. Likewise, then, only one pattern is needed in the shop.

In Fig. 10*b* is shown a rectangular block with one corner clipped off. At the left are the drawings of the right and at the right are the drawings of

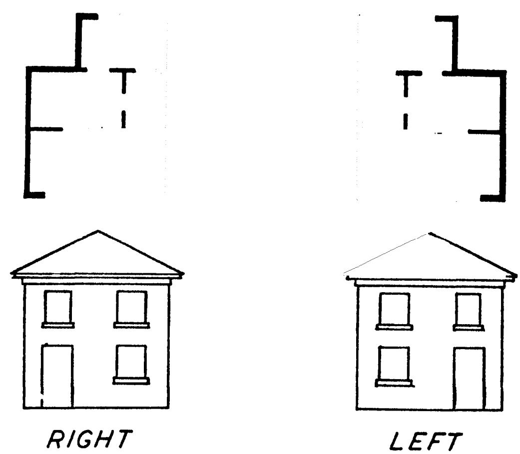


Fig. 10*c*.—Two houses that are right and left.

the left. Above are the pictorial drawings, while below are the orthographic drawings. It is easiest to understand the construction of the left from the right if we imagine the plane of symmetry to be located half way between the two top views.

In Fig. 10*c* are the front views of two houses that are right and left. Above is a section of each showing the arrangement of the first floor.

Figure 10*d* shows views of a skew plate girder bridge. It is made of two large beams built up of plates and angles and braced together. This particular one, as sometimes happens, has its ends arranged at an angle instead of placing the beams exactly opposite as is more often done. In the lower left-hand corner are seen the top view and the front view of a right. Above and to the left are the same two views of the left. Below and to the right are the top and front views, also of a left. The upper left is drawn with a horizontal plane as the plane of symmetry while a vertical plane is used for the construction of the other left. The two will be found to be the same, confirming the statement already made. Also, as stated in III, any brace

in the left will be a left of a corresponding brace which is a right in the big right bridge.

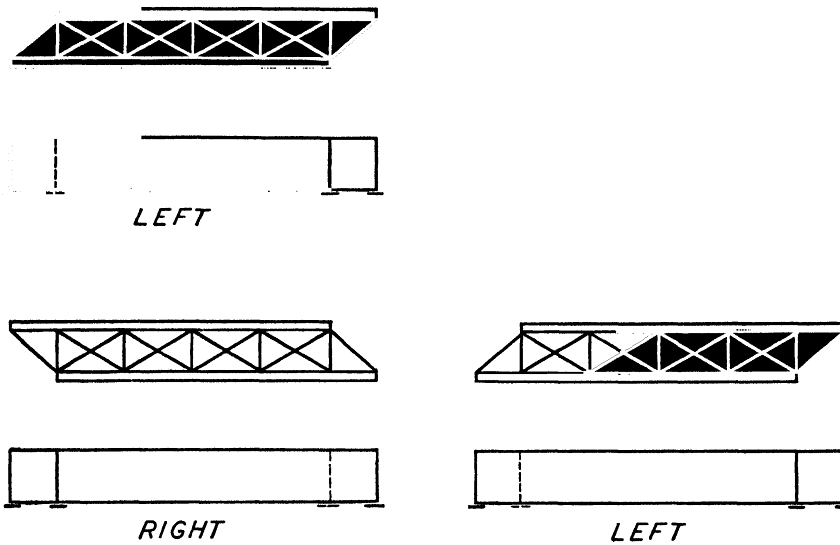


FIG. 10d.

In Fig. 10e are shown the top and front views of a skew hopper, a sloping steel bin for storing material. At the left are seen the two views of the right, while on the right are seen the two views of the left. Now a workman must be able to build the left merely from a drawing of the right.

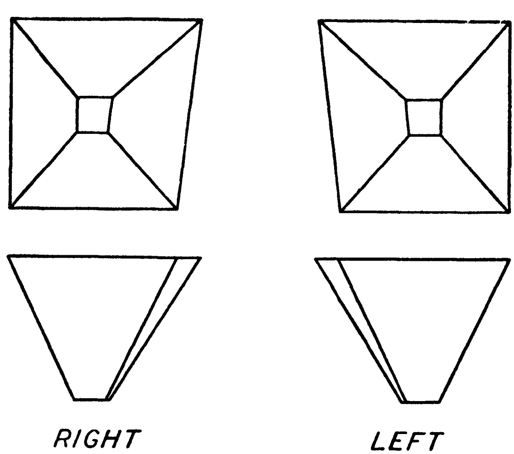


FIG. 10e.—Two hoppers that are right and left.

Perhaps it might be more convenient to give the form shown on the right. Then that would be called the right and the one that must be built symmetrical with the given one would be the left.

A. When a pictorial sketch of a left is to be made from a pictorial sketch or drawing of the right, use a plane *M* as in the first figure of this lesson. Pictorial views are considered in detail in Lessons 18, 19, and 20.

B. When an orthographic sketch of a left is to be made from a pictorial sketch or drawing of the right, beginners will find it best to transform first the pictorial work as mentioned in *A*, and then make the orthographic views of the pictorial left. Experience may enable the student to dispense with this step and make the required orthographic sketch directly.

C. When an orthographic sketch of a left is to be made from an orthographic sketch or drawing of the right, pass a vertical plane through the top and front views parallel to both lines of sight. Then interchange each view about this plane, in each case making the new view symmetrical with the old about the assumed plane. Finally, alter other views to agree with these changes.

The final result will be the same whatever the position of the vertical plane.

D. When a pictorial sketch of the left is to be made from an orthographic sketch or drawing of the right, beginners will find it best to transform first the orthographic work as mentioned in *C* and then make the pictorial sketch from these views. Experience may enable the student to dispense with this step and make the required pictorial sketch directly.

Sometimes the actual object is given, and its left is required. Under these circumstances sketch it as it is and then transform as already directed. Experience may enable one to do the work at a single step.

REQUIRED WORK: LESSON 10

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

10-1. What is the left of an object?

10-2. Bring the flat of your hands together. One hand is the right, the other is the left. Where is the plane of symmetry?

10-3. Is your right hand a left of your left hand?

10-4. What is the left of a left?

10-5. The bridge shown in Fig. 10*f* is symmetrical about two vertical planes. As you enter, at your right is the end post, EP^R. What then is the mark of the end post at the left?

10-6. What is the mark of the end post at the left in Fig. 10*f* as you are leaving the bridge?

10-7. What is the mark of the end post at the right as you are leaving the bridge?

10-8. The two top pieces at the center are marked TC^3. Will they be right and left?

Sheet 10-1 (Fig. 10*h*)

10-9. What is the extreme length of the slotted hole in the rest for the grinder guard?

10-10. State the thickness of the gusset.

Note: A gusset is a thin wedge-shaped bit of metal used to brace two parts of an object together.

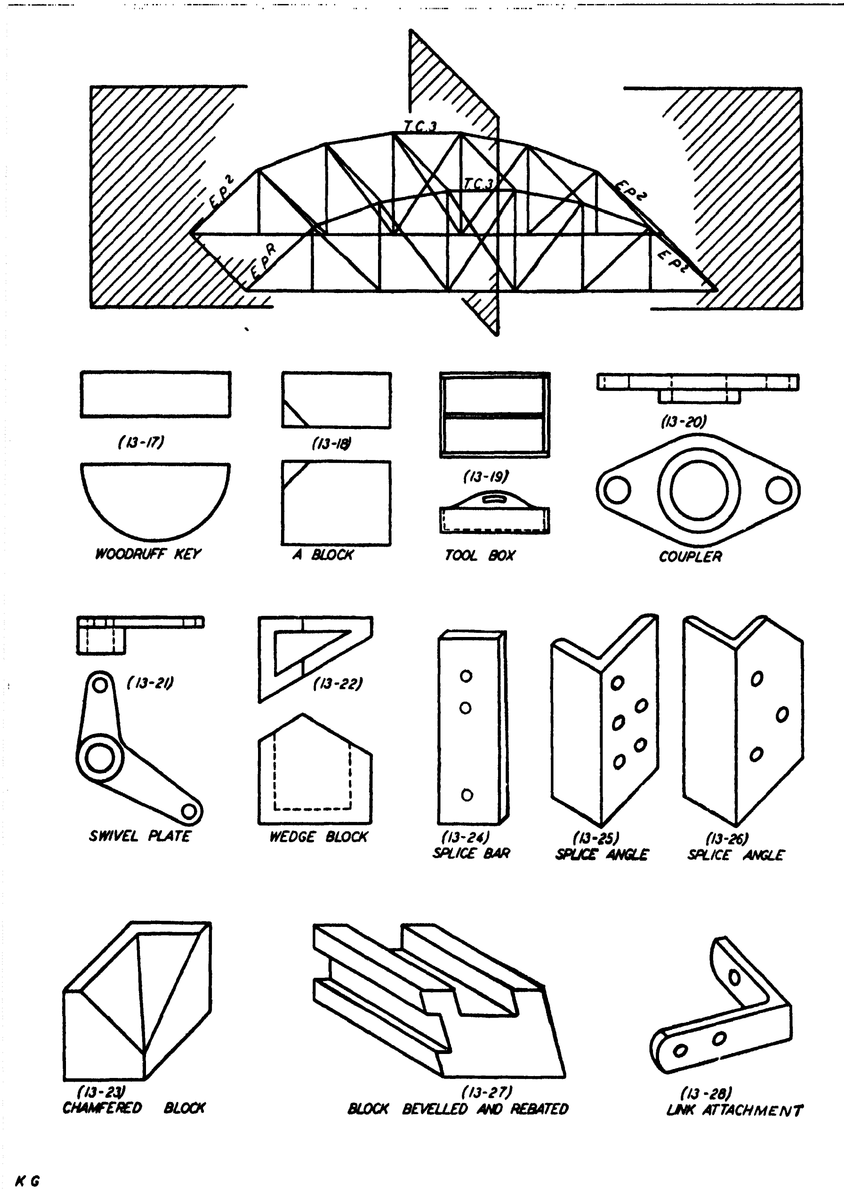

T.C.3
T.C.3
E.P.2
E.P.R
Ep2
Ep2
(13-17)
WOODRUFF KEY
(13-18)
A BLOCK
(13-19)
TOOL BOX
(13-20)
COUPLER
(13-21)
SWIVEL PLATE
(13-22)
WEDGE BLOCK
(13-24)
SPLICE BAR
(13-25)
SPLICE ANGLE
(13-26)
SPLICE ANGLE
(13-23)
CHAMFERED BLOCK
(13-27)
BLOCK BEVELLED AND REBATED
(13-28)
LINK ATTACHMENT
K G

Fig. 10*f*.

SHEET 10-2 (Fig. 10*i*)

10-11. What is the thickness of the metal that is used in the main parts of the guard?

SHEET 10-3 (Fig. 10*j*)

10-12. What is the mark of the longest piece measured from joint to joint?
10-13. How many of such pieces will there be in the entire bridge?

SHEET 10-4 (Fig. 10*k*)

10-14. State the extreme length of the tool.

Sketches

Consider the object mentioned in the following to be the right and sketch the left.

10-15. Figure *a*
10-16. Figure 5*b*
10-17. Figure 6*i*
10-18. Figure (upper) 7*d*
10-19. Figure 8*a*
10-20. Figure 13*a*

LETTERING

Letter in ink upon your sketch paper the numbers 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9 as shown vertically and also the same numbers as shown in inclined

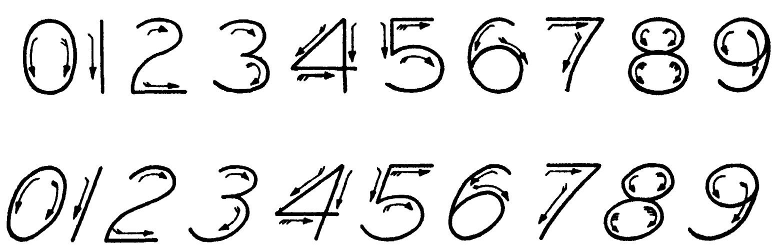


FIG. 10g.

lettering. Figure 4*e* is repeated here for your convenience as Fig. **10*g***. Make the letters first $\frac{1}{4}''$ high, then $\frac{3}{16}''$ high, and finally $\frac{1}{8}''$ high.

SHEETS

All work in this lesson is to be in ink upon tracing cloth.

There are three very interesting ways in which you can check a drawing which shows the left of a given right. First, take the drawing of the left and look at it in a mirror; if it is correct, the mirror image will appear to be exactly the same as in the original. Also one can take the drawing and hold it up to the light and look at it from the back. What you see should again

be like the right. Still a third method of testing the drawing is to put it in the blue-print frame the wrong way; the resulting print will then be like a right. However, your lettering and your numbers will be reversed in all these tests.

SHEET 10-1 (Fig. 10*h*)

The tool rest shown in Fig. 10*h* is at a scale of 3″ = 1′-0″. Copy this, making it twice as large or at a scale of 6″ = 1′-0″. Then underneath, draw the same views of the left of this object and dimension this as well.

Note: In practice, the left is not shown, but the shop is expected to make it merely from the drawing of the right.

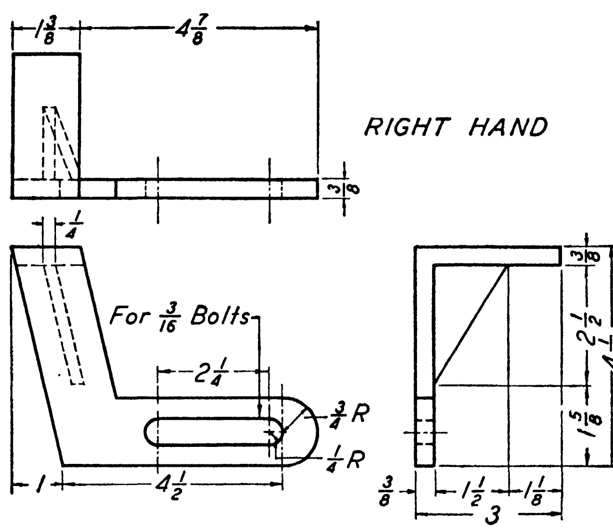


FIG. 10*h*.—A tool rest.

SHEET 10-2 (Fig. 10*i*)

In Fig. 10*i* is shown the left of a part of the grinder guard. Please draw at a scale of 3″ = 1′-0″ and dimension the right. When this is done, it will be found to fit into the other parts of the grinder guard which were given in the last two sheets.

SHEET 10-3 (Fig. 10*j*)

In Fig. 10*j* are shown various views of one half of a symmetrical bridge. On this are placed the marks of the various parts which, when put together, make up the structure. Draw the entire bridge at a scale of 1/32″ = 1′-0″. Dimension it and place upon it the proper marks, being careful that the correct marks, *R* for right and *L* for left, are placed upon the members. The

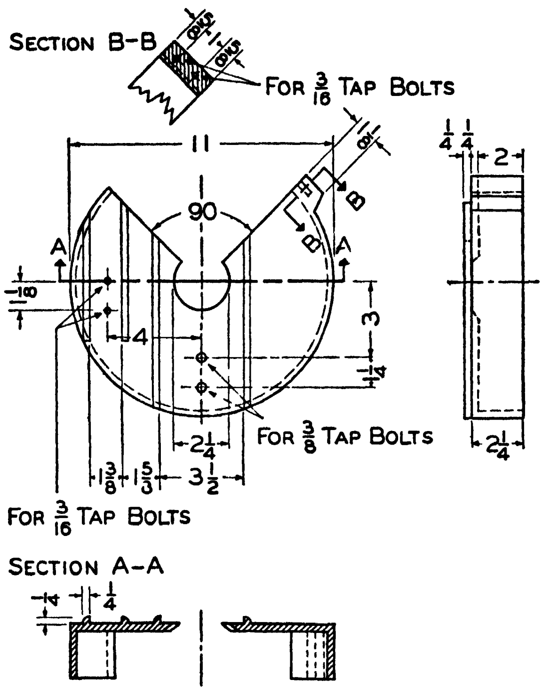


Fig. 10i.—Part of a grinder guard.

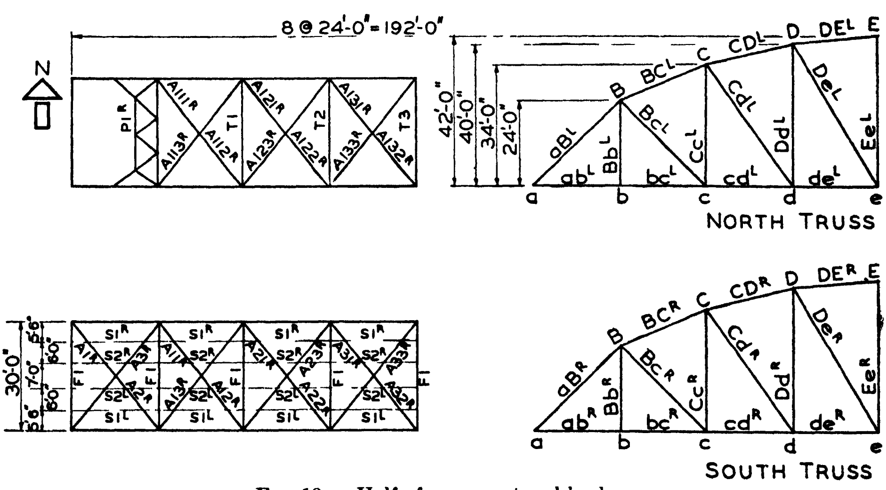


Fig. 10j.—Half of a symmetrical bridge.

expression 8 @ 24 = 192 means that there are eight parts of the bridge, each of them 24′ long, making the entire length, center to center of the ends, 192 feet.

SHEET 10-4 (Fig. 10*k*)

In Fig. 10*k* are shown two views and a section of a tool. Copy and dimension these, making them twice as large or full size. Then, below,

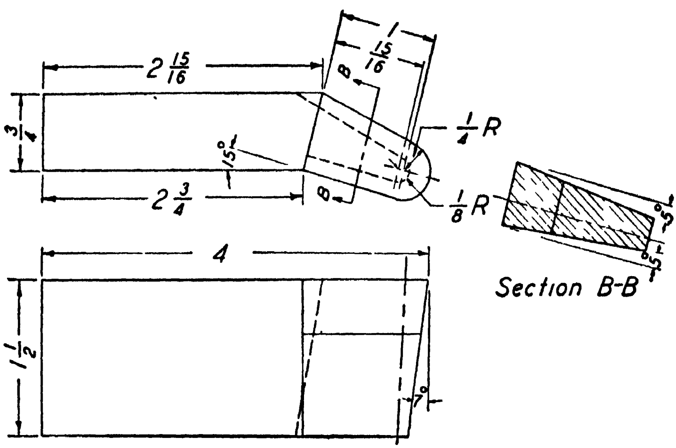


FIG. 10*k*.— An unsymmetrical tool.

repeat the same views and dimension them, making them, however, for the left of the object in the upper part of the sheet.

SHEET 10-5

On page 18 of the text is shown a plan of lots. Draw a left of this, making your drawing twice the size of the original. Letter a title at the bottom of the sheet.

This is the end of Lesson 10. We hope that you have derived sufficient knowledge in regard to right and left so that you can understand these terms either in the drawing room or in the shop.

LESSON 11

AUXILIARY VIEWS

The orthographic views look perpendicularly at the main faces of the object. The direction of these views is:

Vertical.
Horizontal, perpendicular to the front.
or
Perpendicular to the preceding two directions.

Now a view taken in any other direction is termed an "auxiliary view." In this lesson, we will consider only the cases where the direction is part way between two of the directions listed above. Some engineers call such a view the "first auxiliary." However, when the term "auxiliary" is used alone, the "first auxiliary" is intended.

Now any view can be constructed when the relative values of the coordinates of each point are known. For example, in Fig. 11*a*, if we have the lengths

ab, *bc*, and *cd*

bm, *cn*, and *do*

we can construct the figure. If this quadrilateral is a view, we have only the six quantities to get. Really, this construction is merely a location, two dimensions to each point.

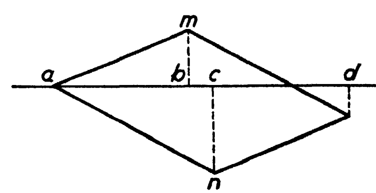


FIG. 11*a*.—Coordinates of a plane figure.

Consider now the block shown in top and front views in Fig. 11*b* and pictorially in Fig. 11*c*. Let it be required to draw an auxiliary view, looking squarely at the inclined or skew face. The necessary view will be in a direction inclined from the vertical 30° towards the horizontal; it is hence a first auxiliary.

First, let us insert in the top view a vertical plane. (In all cases, it is necessary that this reference plane be parallel to the direction of the auxiliary view.) Then the perpendiculars *bm*, *co*, *dn* lie in the inclined face and are seen squarely and in their true size in the top view. The inclined distances *ab*, *bc*, and *cd* are shown in their true lengths in the front view. Now we have the necessary coordinates; any view like Fig. 11*d* with these coordinates properly arranged will be correct.

For two reasons, it is best if the auxiliary view is placed directly opposite the inclined face. It is easy for the draftsman and less likely to contain mistakes, because the lengths *ab*, *bc*, and *cd* are obtained directly by pro-

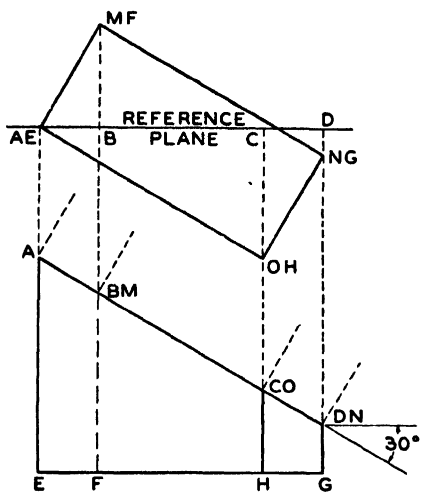


Fig. 11*b*.—A block.

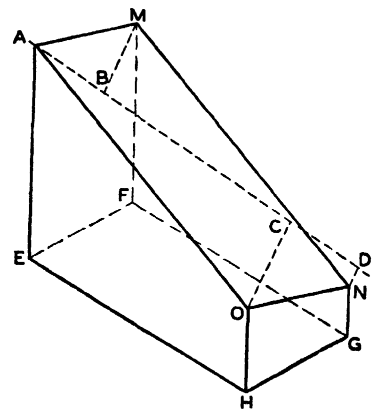


Fig. 11*c*.—The block of Fig. 11*b* shown pictorially.

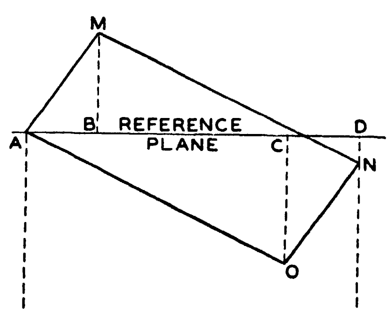


Fig. 11*d*.—Auxiliary view of inclined face of block in Fig. 11*b*.

jection. It is very convenient for those who use the drawing, since it is more readily understood and there is less likelihood of error.

Usually, only a partial auxiliary view is required, that is, a view which represents only the inclined face as in Fig. 11*d*. However, if an entire object is to be shown in the auxiliary, the method is similar, as is shown in Fig. 11*e*. That is, every point on the auxiliary view will be opposite the corresponding point in the front view; also the distance from the reference plane

will be the same in top and auxiliary views. Make the same lines connect as in the object itself. An interesting check is the fact that lines which are parallel in space are parallel in the auxiliary view as well as in the orthographic views.

Thus far, we have considered that the main purposes of drawing were to enable customers to understand what was intended and to direct workers in

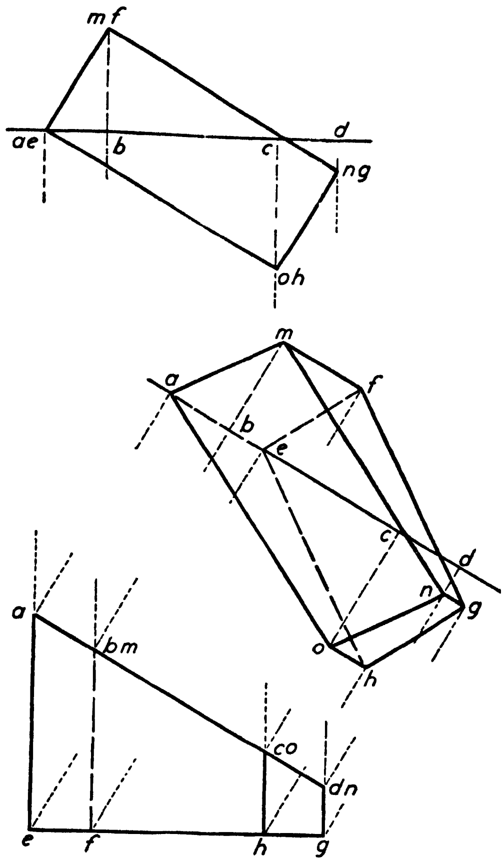


FIG. 11c.

making the objects. However, drawings have another use and one which is quite important. If the drawing has been carefully made to scale, various measurements can be taken from it. These are very useful for three main purposes, namely:

1. In preparing orders.
2. In making estimates.
3. In submitting bids.

As we shall see, the auxiliary views are particularly helpful in getting measurements that do not appear in their true size in the ordinary views.

REQUIRED WORK: LESSON 11

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

11-1. Define "first auxiliary."

11-2. Why is it best to put the auxiliary view directly opposite the inclined face in one of the other views?

11-3. What is a partial auxiliary?

11-4. Explain why *bm* in the auxiliary view in Fig. 11*d* and in the top view in Fig. 11*b* are alike.

SHEET 11-1 (Fig. 11*g*)

11-5. How wide is this foundation?

11-6. State the height of the uppermost step in the foundation.

SHEET 11-2 (Fig. 11*h*)

11-7. State the length of the longest vertical member in the truss.

11-8. Where is the horizontal member that is longest between joints?

11-9. Where is the greatest angle between a top chord and a diagonal?

SHEET 11-3 (Fig. 11*i*)

11-10. What is the length of this connecting rod, center to center of end holes?

11-11. What is the thickness of the web of the main section?

SHEET 11-4 (Fig. 11*j*)

11-12. What is the cross section of the tool held in the upper tool holder?

11-13. What is the over-all length of the tool shown in the lower view?

11-14. What is the cross section of the tool shown in the lower view?

SHEET 11-5 (Fig. 11*k*)

11-15. State the size of the drilled hole in the rounded end of the casting.

11-16. How high is the ½" tapped hole above the very lowest part of the casting?

Sketches

Questions 17, 18, 19, and 20 are to be considered a sketch of the skew portion of the objects drawn in Sheets 11-1 to 11-5 inclusive. Do not sketch the sheet that you draw.

LETTERING

The letters shown in Fig. 11*f* are called small letters in ordinary conversation; the printer calls them "lower case." Important facts upon the drawing are ordinarily lettered in capitals which you have been using in your lettering exercises. Less important matters are lettered in lower case, the capitals being used only in places where we capitalize in ordinary prose.

Copy each set of letters, making the height of the *b*, *d*, *f*, etc., first ¼″, then 3⁄16″, and finally ⅛″. For each case, rule four guide lines: the top and bottom lines being four units apart, the top and the second being one

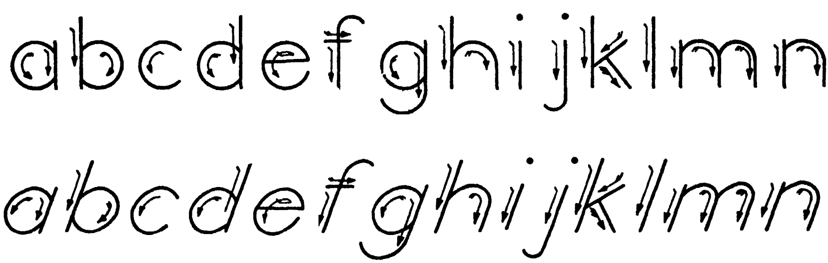


Fig. 11*f*.

unit apart, the second and the third being two units apart, and the third and the bottom being one unit apart. The names of these lines are, in order:

The top line is the Cap Line
The second line is the Waist Line
The third line is the Base Line
The bottom line is the Drop Line

The top of the "*b*" touches the Cap Line; the looped part of the "*b*" lies between the Waist Line on the top and the Base Line on the bottom. The bottom part of "*g*" touches the Drop Line, while the looped part of the "*g*" is between the Waist Line and the Base Line.

SHEETS

All sheets are to be dimensioned and drawn neatly in ink upon detail paper. Be careful to draw each auxiliary view opposite the view from which it is taken, and to show it as though you were looking from the auxiliary view toward the view from which it was derived.

Sheet 11-1 (Fig. 11*g*)

The object shown in Fig. 11*g* is a footing such as is sometimes used where the load brought upon it is inclined as in a steel arch bridge. We have

shown here a front view and a right side view at a scale of $\frac{1}{8}'' = 1'\text{-}0''$. You are to draw a partial side view that is looking only at the horizontal portion, a complete front view, and a complete auxiliary view. Make the scale of your drawing $\frac{1}{4}'' = 1'\text{-}0''$.

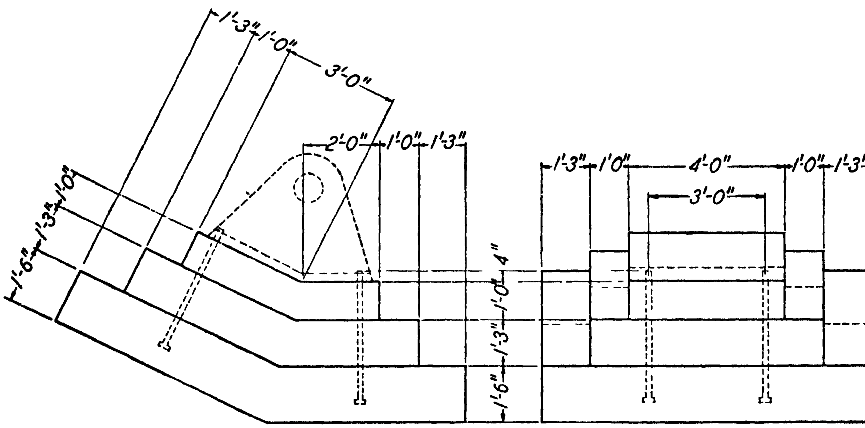


FIG. 11g.—A foundation for an arch bridge.

SHEET 11-2 (Fig. 11*h*)

A bridge 176′ long with a bent upper chord is shown in Fig. 11*h*. Draw at a scale of $\frac{1}{16}'' = 1'\text{-}0''$ the top view and the front view of the left-hand part of the bridge and, above the front view, draw the auxiliary views of

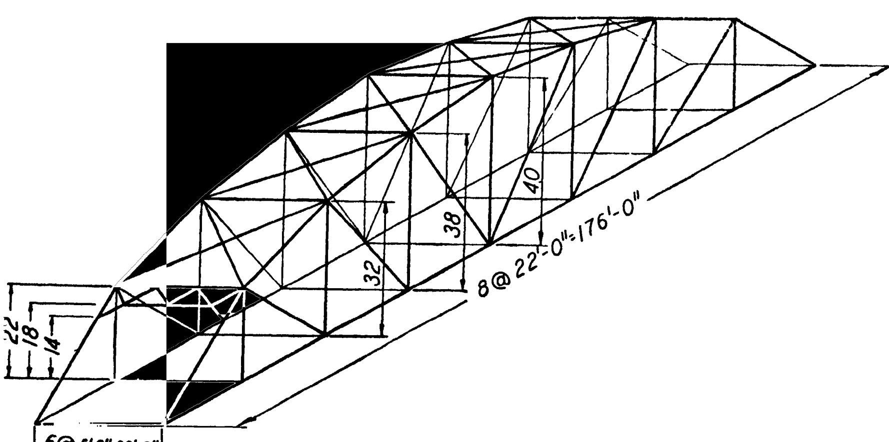


FIG. 11*h*.—A through bridge.

the second, third, and fourth lengths. On each of these auxiliary views, place the inclined lengths along the top chord, the length of a diagonal, and the angle that the diagonal makes with a top chord. Show also an

auxiliary view of the first length and give there similar dimensions—the length of the members and the angle made with the top chord. Dimension the drawing.

SHEET 11-3 (Fig. 11*i*)

In Fig. 11*i* is shown a pictorial drawing of a connecting rod for an automobile. Draw the front and the top views of this rod, together with a revolved section showing the shape of the main part of the rod and a partial auxiliary view of the clamp at the smaller end Make the drawing full size.

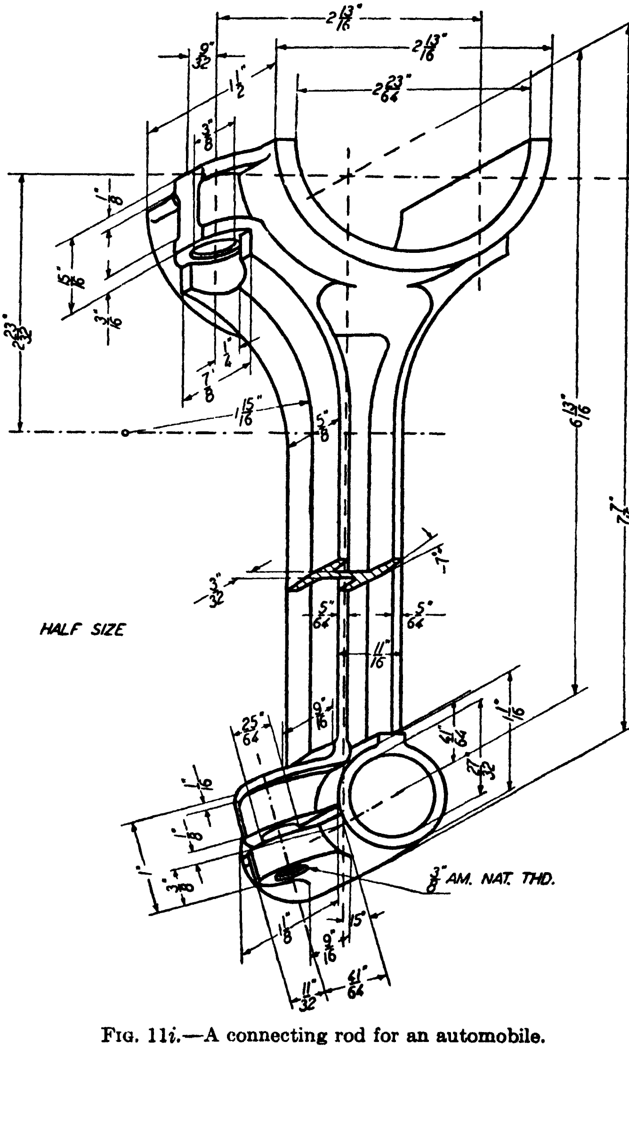


FIG. 11*i*.—A connecting rod for an automobile.

SHEET 11-4 (Fig. 11*j*)

In Fig. 11*j* are shown pictorial dimensioned drawings of a tool holder and a tool. Draw the tool holder first in plan, looking down upon the end

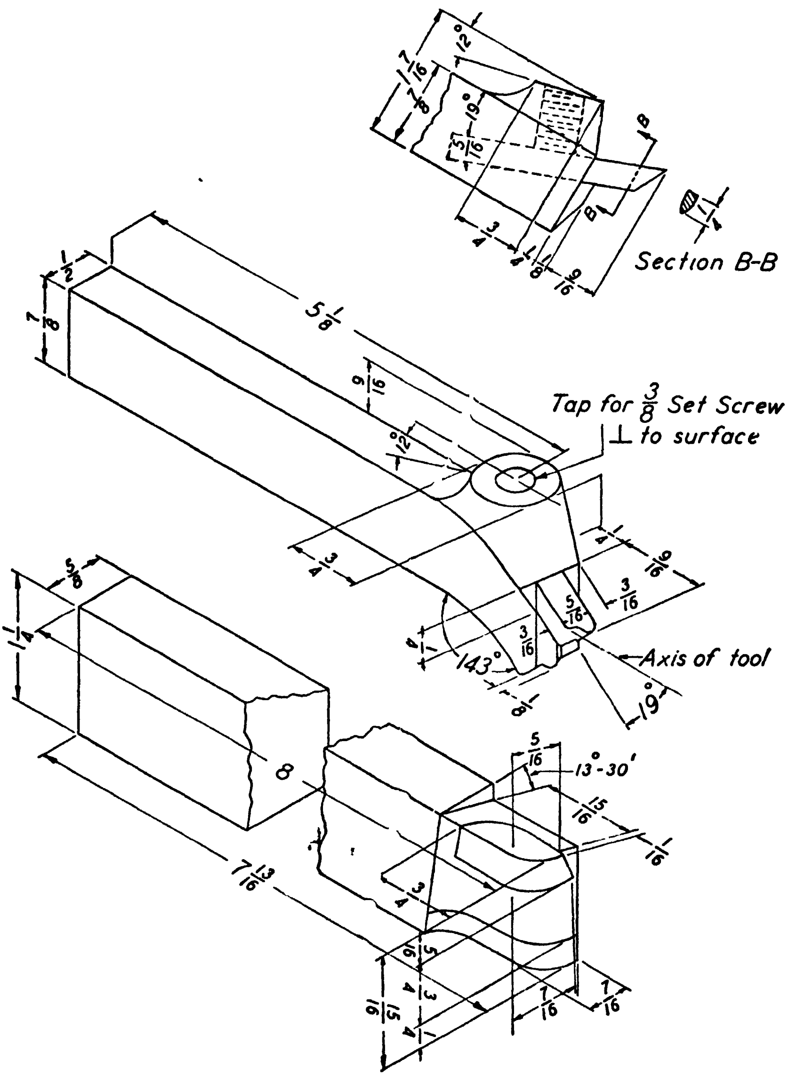


FIG. 11*j*.—A tool.

of the screw. Show the shape of the body of the tool holder by a revolved section. Throw out from the skew end a section through the center of the screw and also give an auxiliary view of the inclined end of the tool holder

and a section through the end of the tool. The shape of the tool is an important item.

Show the plan and the front view of the tool $\frac{5}{8}'' \times 1\frac{1}{4}''$. Also give a section through the end of the tool, showing the arrangement with regard to the working portion of the instrument.

Both objects are to be completely dimensioned and both are to be made full size.

SHEET 11-5 (Fig. 11*k*)

In Fig. 11*k*, a casting is shown pictorially with dimensions. Draw half size a plan, a front view, and a complete side view, as well as a complete auxiliary giving all necessary dimensions.

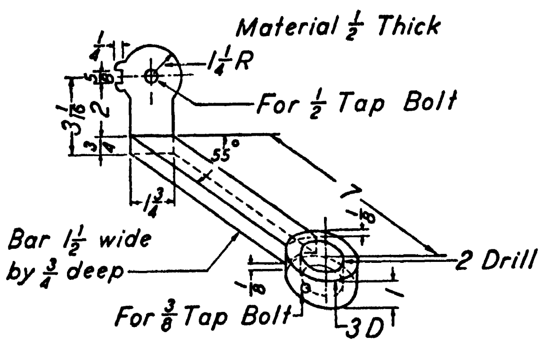


FIG. 11*k*.—A casting.

This is the end of Lesson 11. Be sure that you understand this subject thoroughly because this work will be made the basis for certain lessons that follow.

LESSON 12

SPECIAL AUXILIARY VIEWS

A common application of the auxiliary view is to find the true length of an oblique line. The method is illustrated in Fig. 12*a*. The horizontal

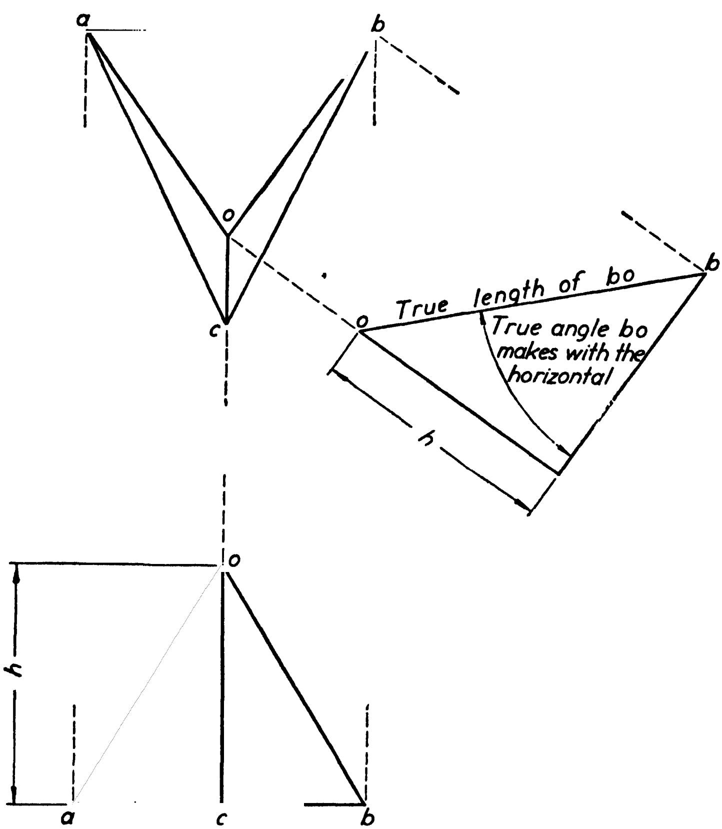


FIG. 12*a*.—A method for finding the true length of an edge of a pyramid.

length as shown is obtained from the top view by projection and the difference of elevation is determined by the front view; that is, *h* in the front view equals *h* in the auxiliary view. The horizontal length of a line and the vertical length of a line are two legs of a right-angle triangle of which the

hypotenuse is the actual length of the line. Therefore, *bo* in the auxiliary is the true length of *bo*. As is quite clear, this auxiliary view shows the angle between the line and any horizontal plane.

Some prefer to consider this operation as a projection upon a vertical plane parallel to the line whose length is wanted. Quite clearly, the method and the results are still the same.

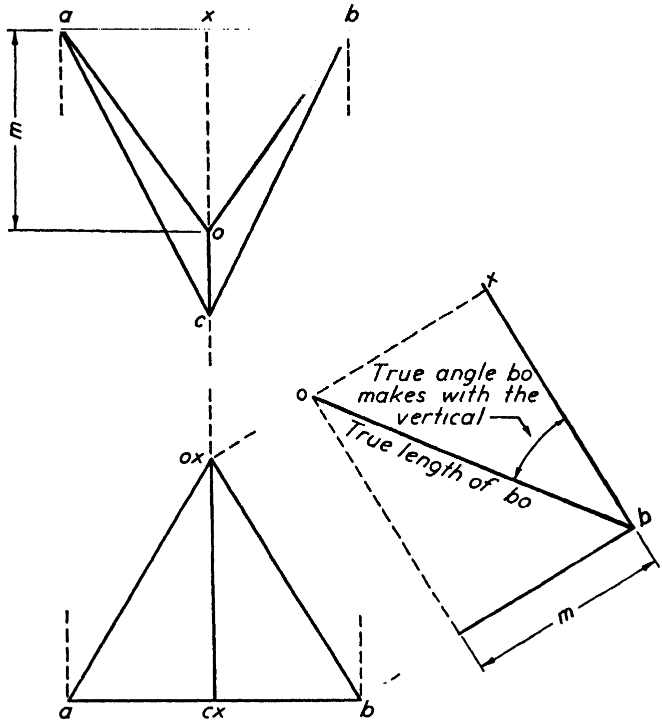


FIG. 12*b*.—Another method for finding the true length of the edge of a pyramid.

The true length of *bo* can also be obtained as in Fig. 12*b*. Here an auxiliary view is drawn opposite *bo* in front elevation. The reference plane in the figure is made a vertical plane through *ab*. Another way of looking at it, is that *bo* is the hypotenuse of a right-angle triangle of which *bx* and *ox* $(=m)$ are the legs. As we have found the two legs, we have the correct value of the hypotenuse.

Another use of the auxiliary view is shown in Fig. 12*c*. Let it be required to find the angle between a horizontal plane and the face *aoc* of the pyramid. Now, a view taken in a direction parallel to the line of intersection, *ac*, of the two planes will show the angle in its true size. Really this is similar to the preceding because we are getting the angle between the slant height and the

horizontal. As before, the horizontal length of the inclined distance is obtained by projection, while the height h is made the same in the auxiliary view as it is in the front view.

A useful application of the first auxiliary is the determination of the point where a line pierces a plane. For example, it might be required to find

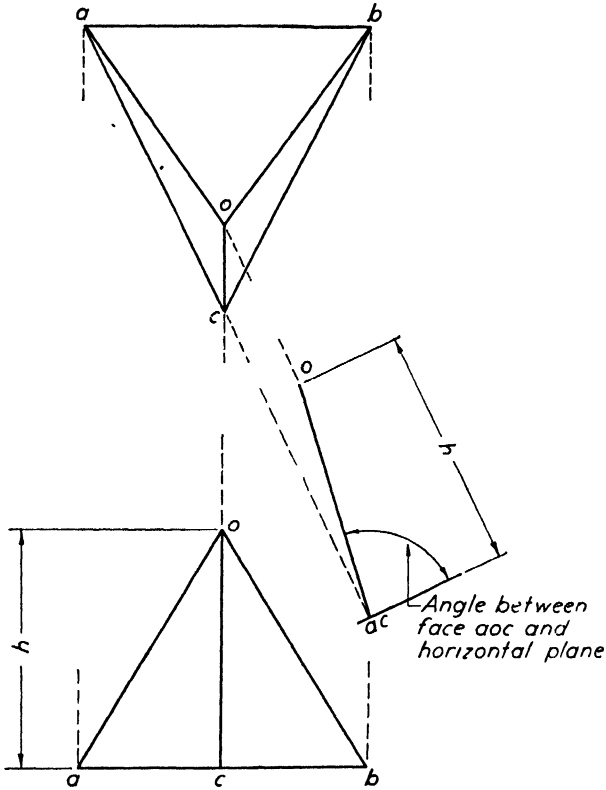


FIG. 12c.—Determination of the angle between base and side of a pyramid.

out where the center line of a pipe went through the side of a hopper or where a column cut through a roof. The problem is solved by drawing an edge view of the plane in question. Now any line in the plane would do to determine the direction of the view but the most convenient one is a level line, that is, a line that is horizontal. A level line can be obtained as in Fig. 12*d*. In the front view, draw a horizontal line *uv*. As *v* is on the line *st*, it must be a point in *st* in the top view directly above.

In Fig. 12*e*, we are required to find where the line *xy* pierces the triangular pyramid, *oabc*. Let us first find where *xy* pierces the plane *oab*. Fortunately, we have here a level line *ab;* a view parallel to *ab* will show the

plane *oab* as a straight line. At the left, such an auxiliary is drawn with the line *xy* also represented. The horizontal length of the plane *oab* is determined from the top view by projection as is shown. The vertical height *h* is made alike in the auxiliary view and in the front view. The plane *oab* can now be drawn as a line in the first auxiliary. Then *x* in the first auxiliary is opposite *x* in the plan and the same height above the base as in the front view. The point *y* can be located in the same manner. Then the real point in the auxiliary view where the line *xy* cu's the plane *oab* is *m*. The point

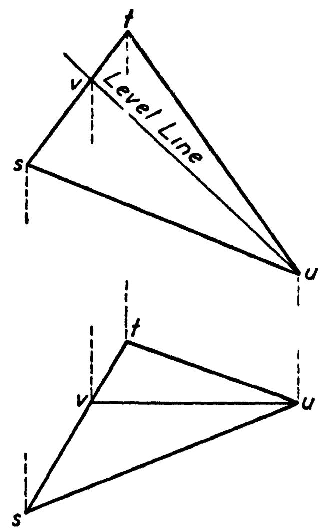


FIG. 12*d*.—Location of the level line.

m in plan is obtained by projecting back from the first auxiliary. The point *m* in the front view is on the line *xy* and directly below *m* in the top view. There is a check here as the height above the base in the auxiliary view must be the same as it is in the front view. The position of *k* is determined in the same manner in the right side view. The point *k* where the line *xy* pierces the plane of the pyramid in the right side view is then the intersection of the line *xy* with the plane of *oac*. This location, *k*, may now be projected back from the right side view to the points on the line *xy* as shown in the front and the top view. This is the intersection *k* of the line *xy* as shown in the two views.

This work will be made much simpler for you if you will try to determine just what views are necessary to get the required quantity. You should then see that the manual operations are merely those necessary to construct a certain view.

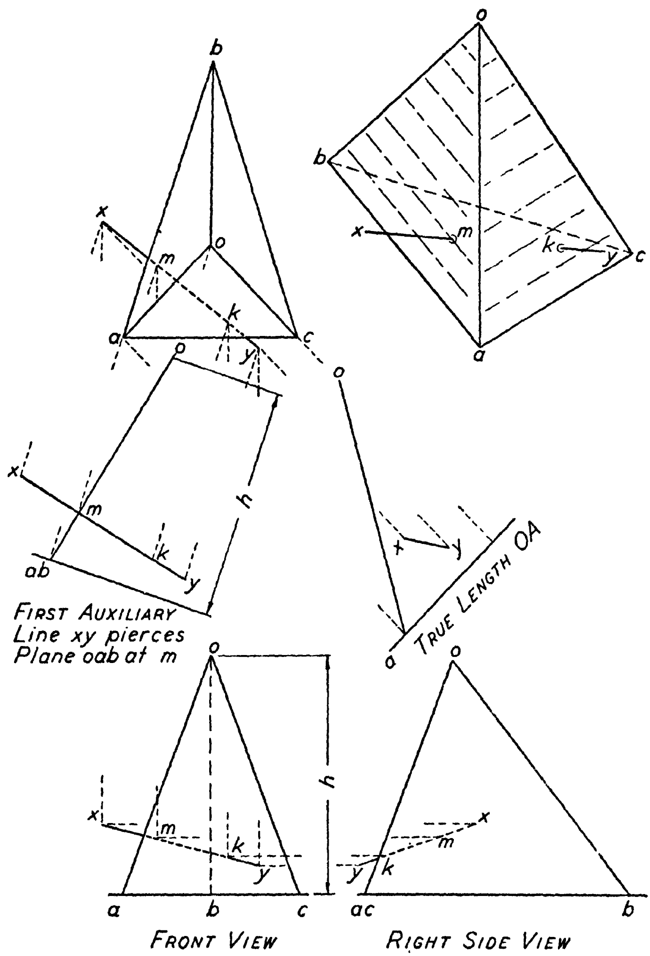


FIG. 12c.—A line passing through a pyramid.

REQUIRED WORK: LESSON 12

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

12-1. State four kinds of measurements that can be obtained by the use of the first auxiliary.

12-2. Which method do you prefer—the view or the projection?

12-3. Explain the method of finding the true length of a line by the auxiliary view.

12-4. How does the method shown in Fig. 12*a* differ from that indicated in Fig. 12*b*?

Sheet 12-1 (Fig. 12*g*)

12-5. What is the usual thickness of the metal in this angle block?

12-6. What is the cross section of the notches projecting in the bottom of the block?

12-7. State the size of the rods for which the holes are cored.

12-8. Determine the inclination of the sides of the block to the horizontal.

Note: This is given in inches on your drawing.

12-9. The two depressed portions on one side of the block are for the compression members coming in from the truss. For what size of timber are they intended?

12-10. Answer the same question for the single recess on the other side of the block.

12-11. What is the approximate height of the block measured from the main base?

12-12. Compare the length of *bo* as obtained by the two solutions given.

12-13. Is the angle with the plane the same in these two solutions? Why?

12-14. What is the value of the angle shown between the face *aoc* and the plane of the base in Fig. 12*c*?

12-15. Is *km* shown in its true length in the top view of Fig. 12*e*?

12-16. How could you get the true length of *km* as shown in Fig. 12*e*?

Sketches

12-17. Sketch the right side view of the pyramid of Fig. 12*b*.

12-18. Sketch the left side view of the line and pyramid in Fig. 12*e*.

12-19. Sketch the right side view of the roof surface of Fig. 12*h*.

12-20. Sketch the solution of a problem in a sheet that you do not draw.

LETTERING

The remaining small letters are shown in Fig. 12*f*. Copy them as you did in the preceding lesson in letters 1/4″, 3/16″, and 1/8″ high. This measurement is to be the total height of such letters as *b* or *d*.

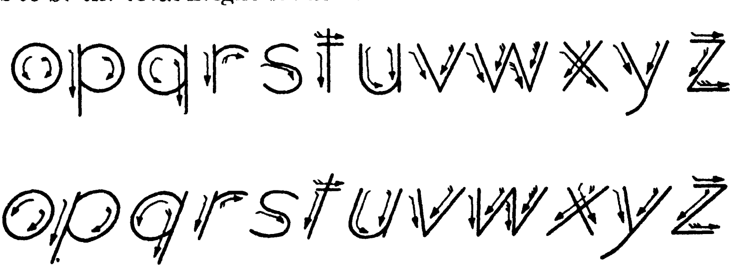


Fig. 12*f*.

SHEETS

All work is to be done in ink upon detail paper and completely dimensioned. Be careful to keep your auxiliary views always opposite the view from which they are taken.

SHEET 12-1 (Fig. 12*g*)

This is the angle block for a Howe truss, a wooden bridge that used to be built a great deal but is now much less used. Notice the holes for the

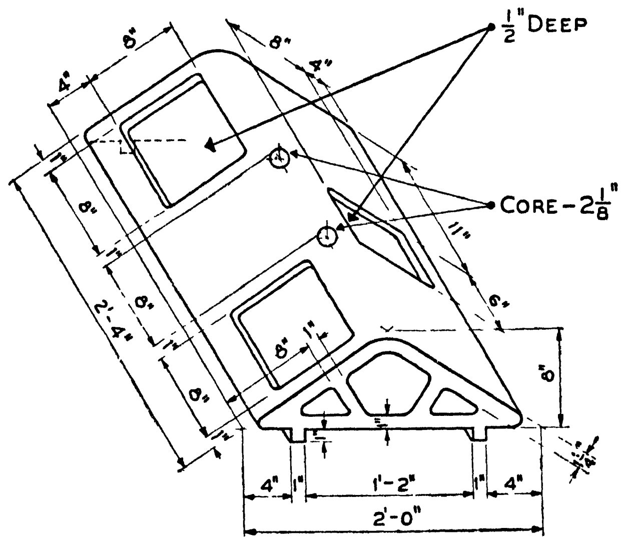


FIG. 12*g*.—An angle block for a Howe truss.

steel rods that pass through the central part of the block, and also the recesses that are inserted to receive the timber members. See Fig. 20*e* for an outline of a Howe truss bridge.

Draw a top view, showing the 24″ × 28″ side. Also draw the front view and the two auxiliary views. If necessary, you can omit a little of the corners of each of these auxiliary views where they are outside the border. This is often done in practice where there is no important construction involved.

The scale is to be 1½″ = 1′-0″. Use the structural system of dimensioning.

SHEET 12-2

The mast (the vertical member) of a derrick is 40′ high, and the base has an elevation of 108.2 feet. The top of the mast is held in position by

four guys (wire ropes). The locations of the lower ends of the guys from the foot of the mast are as follows:

Guy A—N 35° E (from the North 35° toward the East)
62 0 feet—Elevation 128 6 feet.
Guy B—S 62° E 83 0 feet—Elevation 91 5 feet.
Guy C—S 41° W 68 6 feet—Elevation 105 3 feet.
Guy D—N 51° W 58 0 feet—Elevation 108 2 feet.

Note: These four distances were measured horizontally.

Use a scale of 1″ = 32′-0″, draw a plan and a view looking from the south; add the views necessary to determine and mark the length of all guys.

Sheet 12-3

A plate 10″ × 1″ × 14″ has four 1″ diameter holes, 1½″ away from the nearest edges. There is a plate perpendicular to the 1″ plate and ¾″ thick, running so that the center of this plate passes across the center of the 1″ plate at an angle of 10° with the length of the plate. Measure up from the center of the top of the 1″ plate along the center of the ¾″ plate a distance of 3″ at an angle of 15° with the vertical, and locate there a 2″ diameter hole. The ¾″ plate is wedge-shaped in the main but the top is rounded off at a radius of 2½″ from the center of the just-mentioned 2″ diameter hole. Draw at a scale of 3″ = 1′-0″ the top view, the front view, the right side view, and the auxiliary side view.

Note: Draw first the 1″ plate in all views; show the 10″ × 14″ in top view with the 14″ up and down your sheet. Then make the auxiliary view, looking directly at the upright plate. The other views may now be completed.

Sheet 12-4 (Fig. 12*h*)

From point *a* on the ridge of a roof, the ridge runs north. A point *b* on the eaves is 18′ to the west, 12′ to the south, and 10′ below *a*. A point *c* on the eaves is 18′ to the east, 17′ south, and also 10′ down from the point *a*. Connect the points *b* and *c* and also run the eaves north from *b* and *c*. A hip runs from *a* to *b* and from *a* to *c*. The connection *Y* is 24′ directly east of *a* and 8′ below *a*. A tee is located 18′ to the west of *a*, 14′ south of *a*, and 3′ below *a*.

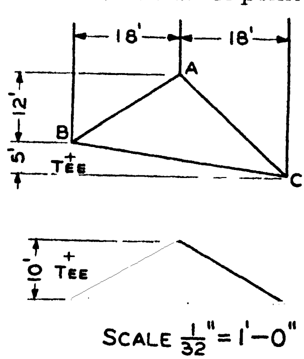


Fig. 12*h*.—A part of a roof.

Draw the top view and the front view of this roof, and also an auxiliary view looking along the level line at the south end of the roof. Determine the point

where a pipe running straight from the Y to the tee will pierce the roof. Make the scale of your drawing $\frac{1}{16}'' = 1'\text{-}0''$ and dimension the roof.

Sheet 12-5

A wall and the edge of a platform are at right angles to one another. Make the line of the wall horizontal on your sheet. A symmetrical hopper 9′ perpendicular to the wall by 7′ parallel to the wall is located with its nearest point 2′ from the wall and 2′-6″ from the edge of the platform. The gate at the bottom, 5′ below the top of the hopper, is located 3′ above the floor and is 1′ wide parallel to the wall and 1′-8″ perpendicular to the wall.

Draw front, top, and right side views at a scale of $\frac{1}{4}'' = 1'\text{-}0'$; also the two auxiliaries, showing the true sizes of the sloping plates.

Select a point a on one of the intersections of the plates. Show this point a in all views as well as in the auxiliary. In each auxiliary, drop a perpendicular to the edge line from a until it hits the top line of the plate at the points b and c. Insert b and c in the top view where bc will be shown in its true length. ab and ac are shown in the true lengths in the corresponding developments (auxiliary views). Construct now a triangle with these three true lengths and you have the actual angle at a between the two plates which meet at that point.

You have now reached the end of Lesson 12. A review at this period would be beneficial.

LESSON 13

THE DOUBLE AUXILIARY

When a surface makes an oblique angle with all directions of view, it is usual to solve by two auxiliary views one of which is a first auxiliary. The

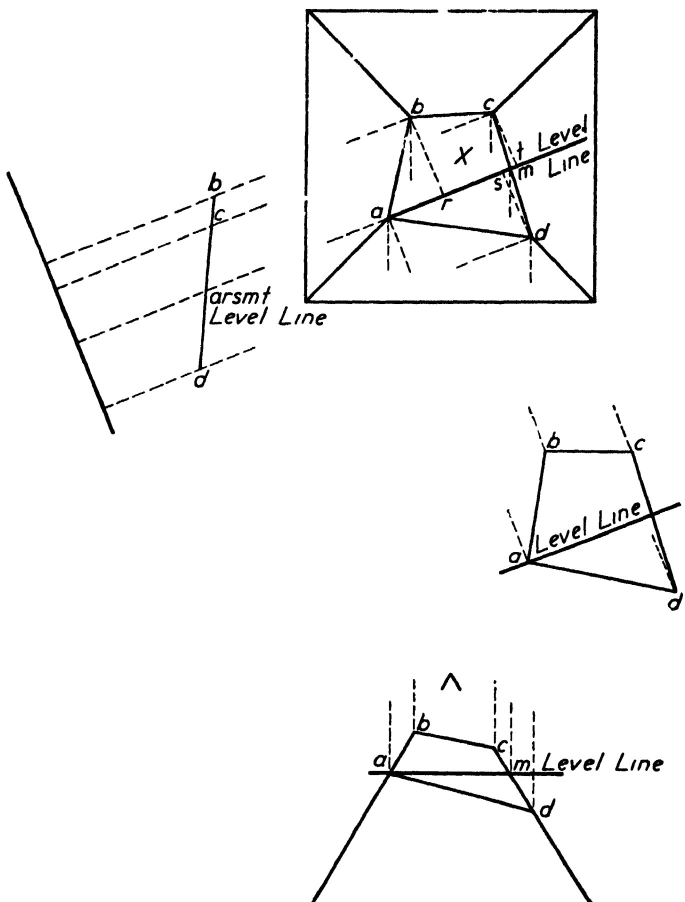


FIG. 13a.—A pyramid cut by a skew plane.

added view is called the "second auxiliary," while the combined solution is termed the "double auxiliary." The first step is to draw a level or horizontal line in the oblique surface. Any line in the surface perpendicular to the

direction of a view would do, but the level line is most convenient and we will use it.

There are certain important facts that are true when the level line is used:

If perpendiculars in space are dropped upon the level line, they will appear to be perpendicular in the top view.

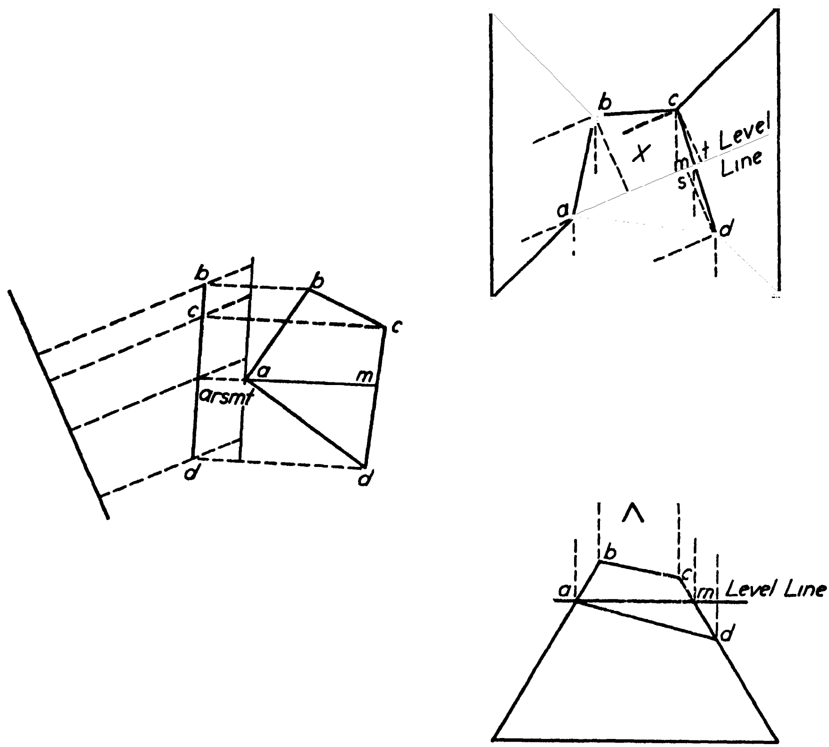


FIG. 13b.—Another solution of problem of Fig. 13a.

The length of the level line and the parts into which it is divided are seen in their true size in the top view. The lengths of the perpendiculars to this level line are seen in their true size in a first auxiliary, looking parallel to the level line.

In connection with Fig. 11*a*, we showed you how any view might be drawn if the coordinates of each point could be obtained. In this lesson, we have already shown you how each set of coordinates might be determined. We can obtain the lengths along a straight line and also the distances perpendicular to them.

Let us illustrate by an example:

A square pyramid is cut by a skew plane to form the surface *abcd*, as seen in Fig. 13*a*. It is required to draw a true view of the surface.

First draw the level line *am* (make it horizontal in front view, then project it to obtain actual location in top view).

In the top view, draw perpendiculars to the level line *am*—from the point *b* to *r*, from *d* to *s*, and from *c* to *t*. Then *ar*, *rs*, and *st* are true distances.

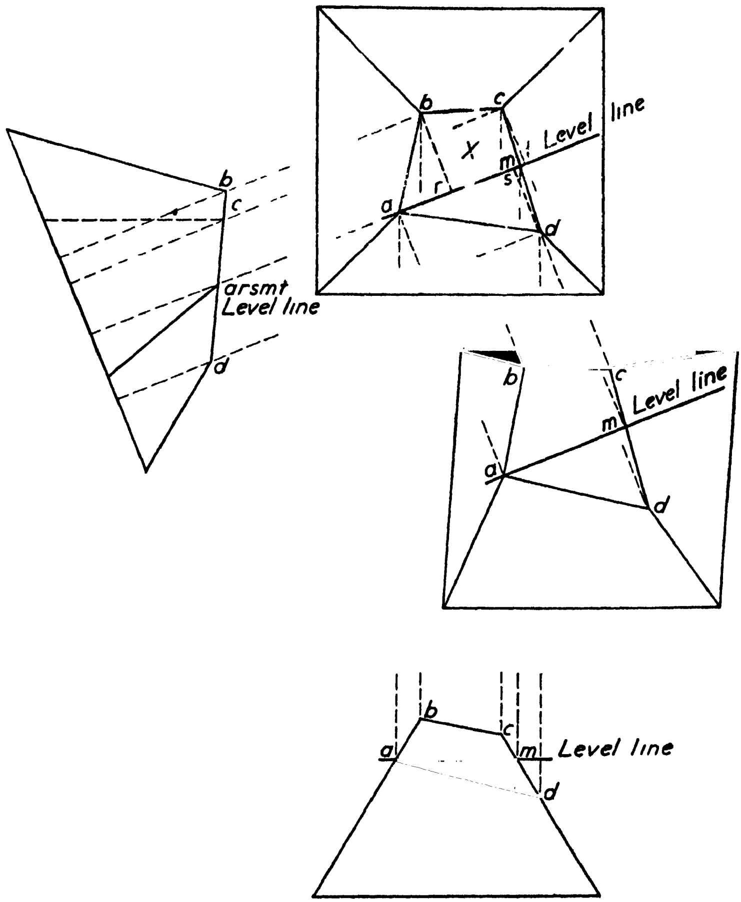


FIG. 13*c*.—A complete solution.

Construct the first auxiliary looking parallel to the level line. Opposite *d* on the top view and at a height above the base shown in the front view will be *d* as seen in the first auxiliary; similarly, *b*, *c*, and the level line are located. Then *br*, *ds*, and *ct* are shown in their true size in this view.

Locate the true view of the surface by selecting a position for the level line. The lengths *ar*, *rs*, and *st* are obtained by projecting them out perpendicularly from the top view. The distance of *b* from the level line on this last view is made equal to *br* on the first auxiliary and similarly for *sd* and *ct*.

The location of the first line on the second auxiliary, the level line, is determined merely by the desire to make a nice appearing drawing.

The second auxiliary might have been put opposite the first auxiliary as is shown in Fig. 13*b*. The important thing to consider is the convenience of the workman. Sometimes one and sometimes the other method is best. For this particular example, however, the position of Fig. 13*a* is better because then the workman sees more clearly where points in the second auxiliary view (this is the view from which he must work) belong.

Sometimes it is desired to show the whole object as seen from a direction perpendicular to the skew surface. In such cases, the same methods are merely continued as shown in Fig. 13*c*.

Some prefer to consider both first and second auxiliaries as projections upon a plane. Then the plane for the first auxiliary is perpendicular to the level line, while the plane of projection for the second auxiliary is parallel to the skew surface. This method of working the problem is correct and may be used; it is, however, rather complicated and hard for most draftsmen to understand.

REQUIRED WORK: LESSON 13

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

13-1. Define the double auxiliary.

13-2. State briefly the principal operations necessary to draw the double auxiliary.

13-3. Will the double auxiliary give the correct value of the length *bd* in the various figures?

13-4. Will the double auxiliary show the true values of the angle *abd* in the skew plane?

SHEET 13-1 (Fig. 13*c*)

13-5. What is the distance between trusses?

13-6. State the greatest height of the truss.

13-7. Determine the amount of the skew (the skew is the deviation of the trusses from a position opposite one another).

13-8. What is the angle of skew?

13-9. State the lines in the truss that are level.

13-10. Are the top struts shown in their true length in the front view? (The top struts are members in the top parallel to the end of the bridge.)

13-11. Answer the preceding question for the top struts as seen in the top view.

13-12. Are the angles at the X intersections in the top view shown in their true value?

13-13. Will the lengths of the pipes in Sheet 13-2 be greater or less than the horizontal measurements?

13-14. Will the area of the skew face of the 24″ pipe in Sheet 13-3 be greater or less than the area of the cross-section?

13-15. Would it make any difference in the area if the angle of 55° was measured from the vertical rather than the horizontal?

13-16. Would the plates in Sheets 12-3 and 13-5 weigh the same?

Sketches

13-17.
13-18. Sketch the required views for Sheets 13-1, 13-2, 13-3, 13-4, and 13-5, omitting
13-19. the sheet that you draw.
13-20.

LETTERING

Letter BOLT AND NUT as shown in Fig. 13*d* in vertical letters, also inclined letters. Make each $\frac{1}{4}''$ high, $\frac{3}{16}''$ igh, and $\frac{1}{8}''$ high.

Fig. 13*d*.

SHEETS

All sheets are to be in ink upon detail paper and are to be dimensioned. Try to show clearly your method of operation, so you can understand it years later.

Sheet 13-1 (Fig. 13*e*)

Draw front and top view of half of this skew bridge and first and second auxiliaries of the oblique top faces. The scale is $\frac{1}{16}'' = 1'\text{-}0''$. Give scaled lengths for diagonals and true scaled angles of diagonals with struts and top chords.

Sheet 13-2

A surveyor's notes contain the following data:
Note: A surveyor's measurements are taken in a horizontal plane:

		Elev.
$AB = 44\ 5$	Angle $ABC = 160°\text{-}30'$	$A = 220\ 6$
	Line deflects to the right as we go from A to B to C	$B = 188\ 4$
$BC = 38\ 9$	Angle $BCD = 142°\text{-}10'$	$C = 228\ 3$
	Line deflects to the left as we go from B to C to D	$D = 245.6$
$CD = 63\ 4$		

Draw plan and front elevation and determine all lengths and both angles in space. Use a scale of $\frac{1}{32}'' = 1'\text{-}0''$.

Note: Draw a level line from the end of one line to the other line, produced if necessary. Consider that these three lines form an oblique plane and solve as in the standard case.

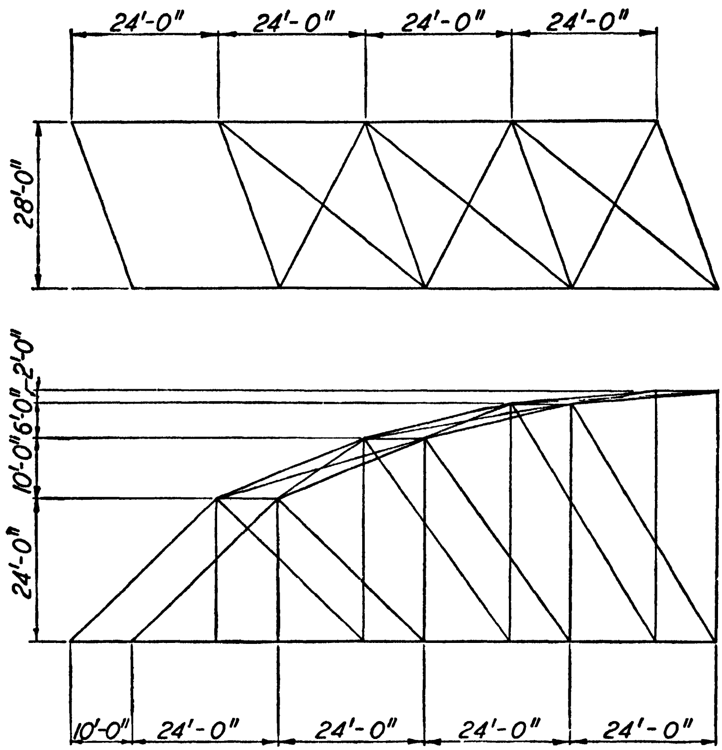


Fig. 13e.—A skew bridge.

Sheet 13-3

A horizontal circular pipe 24″ in diameter is cut so that a horizontal line at the end of the pipe makes an angle of 110° with the center line. The angle between this cutting plane and the horizontal is 55°.

Draw plan, a vertical section of the pipe and the two auxiliaries so that the true area of the end of the pipe is known. Use a scale of 1½″ = 1′-0″.

Sheet 13-4

Solve Sheet 13-3 again with the pipe octagonal and 24″ in extreme diameter with one diagonal horizontal.

Sheet 13-5

Solve Sheet 12-3 with the plate which was vertical tilted to the left by 20°.

This is the end of Lesson 13. Try to do as much as you can yourself. If you need help be sure that you understand just why everything is done.

LESSON 14

FURTHER USE OF THE DOUBLE AUXILIARY

As the direction of view in the second auxiliary is square to the skew surface, it follows that we can get the graphical measure of any quantity in that area. Any angle and any distance is shown in its true size. Thus we may determine:

The length of any line.
The value of any angle.
The area of any surface.
The angle of the skew plane with the horizontal (from the first auxiliary).

As a review, another problem will be inserted here.

An octagonal prism, Fig. 14*a*, is cut by a skew plane so that three consecutive edges have the lengths 3″, 4″, and 9″. Find the actual area of the skew face.

Draw the top view and the front view with the cut edges as stated. Then draw the level line 3″ high in the front view and in the top view Next draw the base line perpendicular to the level line in the top view, and construct the first auxiliary.

The three ordinates 3″, 4″, and 9″ determine and check the location of the cutting plane in the first auxiliary. Finally, the second auxiliary is drawn beginning at the level line in the double auxiliary which was taken far enough away to leave room for the view. Each point was located opposite its position in the top view and as far away from the level line as is shown in the first auxiliary.

There are in all auxiliary views two kinds of problems. In the first, the object is complete in the ordinary views and an auxiliary view is to be made of the whole. In the second, the auxiliary view is used to complete the ordinary view. In other words, in the latter case the points are first located on the auxiliary and then projected back to the ordinary views.

We may classify sheets in this and the preceding lessons as follows:

Ordinary Views Complete	Completion in Auxiliary Views
11-1, 11-2, 11-3, 11-4	11-5
12-1, 12-2	12-3, 12-4, 12-5
13-1, 13 2, 13-3, 13-4	13-5
14-1, 14-2	14-3, 14-4, 14-5

We may repeat here what has already been said, that lines parallel in space appear to be parallel in every view.

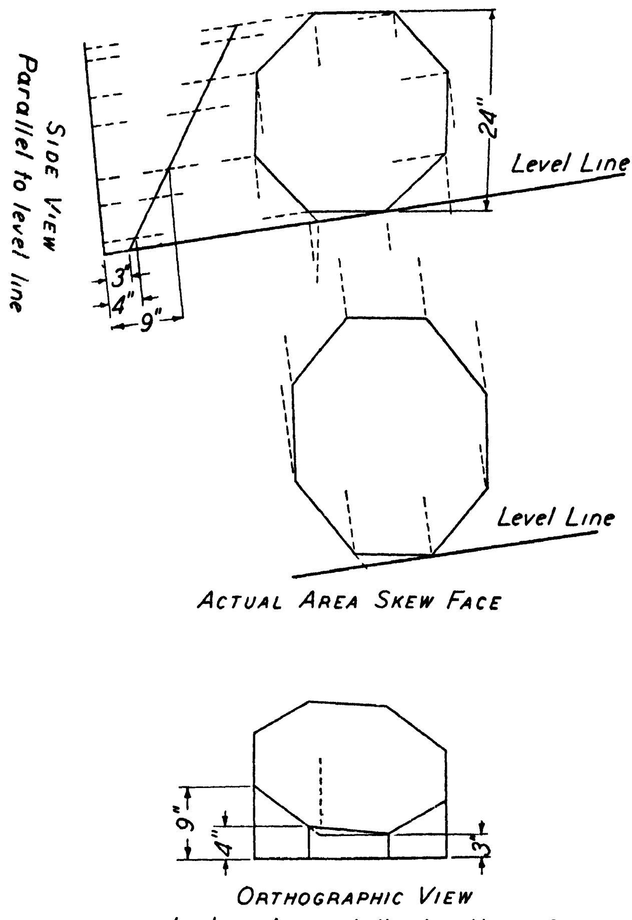


FIG 14a —A truncated octagonal prism.

PENCIL CLOTH

Pencil cloth in appearance and treatment much resembles tracing cloth. It must not be folded or crinkled and contact with water ruins it. It differs in that it does not require powdering and that the drawing is made directly upon the cloth in pencil. Under ordinary circumstances, the drawing is first made upon the cloth.

The cloth is strong and durable; it will not tear like tracing paper.

LETTER SPACING

The table gives the proportion that the width of the letter is to the height, also proportion to height of space needed on either side. The height for small letters is the total height of *b*, *d*, and so forth. To get total distance between two letters add the corresponding spaces. Thus to get the distance between the *A* and *T* in *AT*, add the proportion for the right-hand space (*R* space) for *A* and the proportion for the left-hand space (*L* space) in *T* and multiply by the height. In making *AT* ½″ high, *A* should be 1.00 × ½ = 0.50″ wide and the space between *A* and *T* should be (0.10 + .05)½ = .08″. Use the same values for inclined and vertical lettering.

Letter	Capitals			Small letters			Number	*L* space	Main number	*R* space
	L space	Letter	*R* space	*L* space	Letter	*R* space				
A	0.10	1.00	0.10	0.12	0.60	0.18	0	0.15	0.70	0.15
B	0.30	0.80	0.20	0.18	0.60	0.12	1	0.30	0.05	0.30
C	0.15	0.80	0.18	0.12	0.54	0.12	2	0.18	0.70	0.20
D	0.30	0.83	0.15	0.12	0.60	0.18	3	0.15	0.75	0.20
E	0.30	0.83	0.10	0.12	0.60	0.12	4	0.10	0.95	0.15
F	0.30	0.77	0.10	0.10	0.54	0.10	5	0.20	0.77	0.15
G	0.15	0.80	0.18	0.12	0.60	0.18	6	0.15	0.72	0.18
H	0.30	0.83	0.30	0.18	0.55	0.15	7	0.10	0.70	0.15
I	0.30	0.05	0.30	0.18	0.02	0.18	8	0.20	0.80	0.20
J	0.05	0.70	0.27	0.12	0.30	0.18	9	0.12	0.72	0.15
K	0.30	0.90	0.15	0.18	0.50	0.12				
L	0.30	0.68	0.05	0.18	0.02	0.18				
M	0.30	1.00	0.30	0.18	1.00	0.18				
N	0.30	0.83	0.30	0.18	0.54	0.18				
O	0.15	0.83	0.15	0.12	0.60	0.12				
P	0.30	0.83	0.05	0.18	0.60	0.12				
Q	0.15	0.83	0.15	0.12	0.60	0.18				
R	0.30	0.83	0.15	0.18	0.45	0.10				
S	0.18	0.88	0.12	0.12	0.52	0.12				
T	0.05	1.00	0.05	0.10	0.30	0.10				
U	0.27	0.78	0.27	0.18	0.54	0.18				
V	0.10	1.00	0.10	0.10	0.60	0.10				
W	0.15	1.35	0.15	0.10	0.95	0.10				
X	0.15	1.00	0.15	0.12	0.60	0.12				
Y	0.10	1.00	0.10	0.10	0.60	0.10				
Z	0.15	1.00	0.15	0.12	0.60	0.12				

The spacing between two words in capitals should be the *R* space for the last letter of the left-hand word, plus the height of the letters, plus the *L* space for the first letter of the right-hand word. For small letters, add the

height to the loop, about two-thirds of the total height, instead of the entire height.

Thus in lettering "A Tee" in letters ½" high, the distance between the *A* and the *T* should be $(0.10 + 1.00 + .05)\frac{1}{2} = 0.57''$.

For compressed lettering, lessen the widths of the letters and the spacing proportionately. For extended letters, increase the widths of the letters and the spacing proportionately. Thus all widths and spaces might be increased one quarter or, on the other hand, made 90% of those listed.

Except in title or display lettering, one should not stop to compute letter sizes or spacing. However, it is valuable as suggesting to the student the way his work should appear.

This is a rather short lesson; please use the opportunity to review thoroughly, especially the auxiliary views. Try to understand this work and to know not only that the lines must be drawn a certain way but why they must be so drawn.

REQUIRED WORK: LESSON 14

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

14-1. In Fig. 13*a*, suppose that the true size of the upper sloping face is found by the first auxiliary, while the surface *abcd* is found by the second auxiliary as shown. Will the two lengths of *bc* as found be alike?

14-2. Would two level lines drawn in a skew plane be parallel?

14-3. If the two level lines in the skew plane were viewed in the first auxiliary, would one see the true distance between them?

14-4. If two level lines were drawn in the skew plane, and shown in the second auxiliary, would they be parallel there?

Sheet 14-1 (Fig. 14*b*)

14-5. Which plate in the hopper will have the largest area?

14-6. Which plate makes the greatest acute angle with the horizontal?

14-7. Determine the shortest diagonal intersection line between the plates.

Sheet 14-2 (Fig. 14*d*)

14-8. Will the combined areas of the roof be more or less than the area of the top view?

14-9. At the intersection of planes *A* and *B* there are two angles between eaves and hip as seen in plan. Which is the larger?

14-10. The intersection between planes *A* and *B* (the hip) will appear in the development of *A* and the development of *B*. Will the two lengths be alike?

Sheet 14-4 (Fig. 14*f*)

14-11. If the brace were at the top of the flag pole. would its length be increased or decreased?

14-12. Which side of the roof is the steeper, the 16′ or the 20′ side?

14-13. Which hip will be most sharply pitched? (Will have the largest angle with the horizontal?)

SHEET 14-5 (Fig. 14*g*)

14-14. Which hip is the longer, *ab* or *ac*?
14-15. Which hip makes the larger angle with the horizontal?
14-16. Should half of the lines of the skylight be parallel to the eaves?

Sketches

14-17, 14-18, 14-19, 14-20. Sketch the required views for sheets 14-1, 14-2, 14-3, 14-4, and 14-5, omitting the sheet that you draw.

LETTERING

Letter in capitals.

SYM. ABT. THIS LINE

The first *S* is to be 50% higher than the other letters. Use the lettering table to make the first copy in vertical and inclined lettering in which all letters except the first are ¼" high. Then copy these as nearly as you can by eye, first 3/16" and then ⅛" high for everything but the first *S*.

SHEETS

All sheets are to be in pencil upon pencil cloth and are to be dimensioned. The fact that your drawing is made in pencil must not prevent you from making a neat and carefully lettered drawing. As far as possible, space the views so as to avoid interferences and to keep all work within the border lines.

SHEET 14-1 (Fig. 14*b*)

A skew hopper is shown in Fig. 14*b*. Draw top, front, and right side views at a scale of ¼" = 1'-0"; it will be advisable to omit a little of the left-hand corner of the side view in order to obtain plenty of room. Construct the first auxiliaries for the two skew sides and then develop all sides by revolving them as shown in Fig. 14*c*. However, the dimensions are still those determined by the double auxiliary; in fact the revolved view is really a double auxiliary. The reason for this position is that it makes very clear to all users of the drawing just where the development belongs.

When an area is revolved in plan about a level line, all points travel perpendicularly to the level line. This might have been reasoned out from the construction of the second auxiliary. However, it will do no harm if the fact is emphasized that both methods of procedure bring the same final result.

SHEET 14-2 (Fig. 14*d*)

In Fig. 14*d* is shown the plan of a hip roof with the beginnings of the hips. Copy this at a scale of ⅛" = 1'-0". Then draw the first auxiliaries for each section of the roof. We have one point on this first auxiliary, the eaves, which is best to take as the base. The bevels as stated in Fig. 14*d*

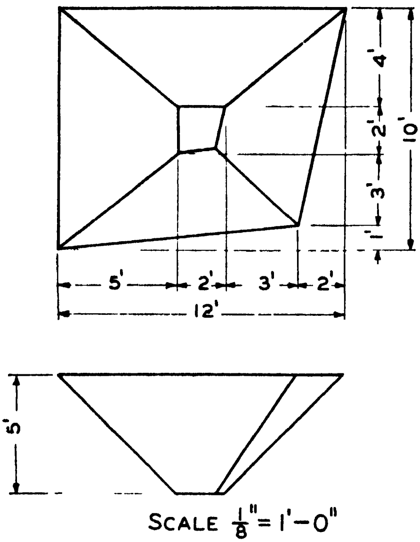


FIG. 14b.—A skew hopper.

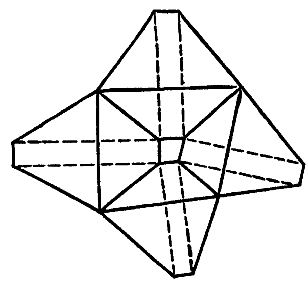


FIG. 14c.—Method of revolving sides.

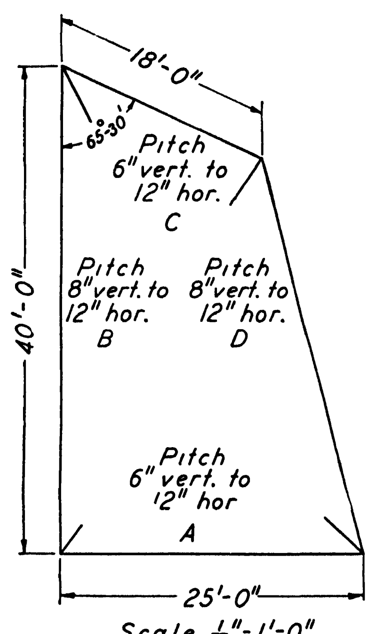


FIG. 14d.—Part of a roof.

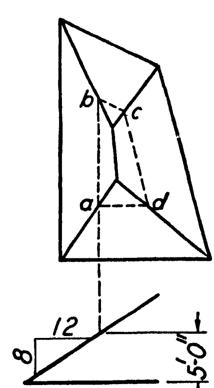


FIG. 14e.—A roof.

give us the angles of inclination. For example, if the inclination is 8″ vertical to 12″ horizontal, lay off on the base 12 units, say, 12 quarter inches or 3″ horizontally, and 8 quarter inches or 2″ vertically.

It will be necessary to determine the hip lines in order to solve this problem. To do this, first find as in Fig. 14*e* the points in the first auxiliary 5 feet (any convenient distance can be used) above the base as is shown at one point, thus determining the line *ab*. In a similar way from the first auxiliaries the lines *bc*, *cd*, and *ad* are located. Then the intersection of these dotted lines are points on the nearby hips.

Make the second auxiliaries as in the preceding plate, see Fig. 14*c*, by rotating the roof areas about the eave lines.

Sheet 14-3

A mining engineer's notes read as follows:

	Course	Distance	Pt.	Elev. Ground	Elev. Top of Vein
ab	S 21°-30′ E	400 0	*a*		600.0
bc	Due West	600 0	*b*		150.0
cd	N 78°-15′ E	465.0	*c*		500.0
			d	700.0	

Make north the top of the sheet.

The strike is the bearing of a level line in the surface of the vein.

The dip is the angle of the vein from the horizontal measured perpendicular to the level line.

The shortest distance from *d* to the plane will be perpendicular to the level line in the top view and perpendicular to the plane in the first auxiliary.

Place this information on drawing { Scale 1″ = 200′
Coal weighs 85 lb. per cubic foot.
Strata 6′ thick perpendicular to vein.

Please print the following on your sheet with answers obtained by you:

Strike
Dip
Short tons (2000 lb.) of coal in *abc*
Cost vertical shaft at *d* to top of coal ($15 per lineal ft.) ——————
Cost of inclined shaft at *d* to top of coal, made perpendicular to vein ($20 per lineal ft.) ——————
Shortest distance between *ac* and perpendicular shaft ——————
Bearing of perpendicular shaft ——————
Angle between perpendicular shaft and horizontal plane ——————

A variation from correct results in angle of over 1°, in distance of 20 feet, in cost $500, in tonnage of 100, will be sufficient cause for the rejection of this plate.

Sheet 14-4 (Fig. 14*f*)

In Fig. 14*f* is shown a plan and a front view of a part of a roof. Please copy these drawings at a scale of $\frac{1}{16}'' = 1'\text{-}0''$ and add a first and second auxiliary of the skew portion of the roof. The exact location of the strut can be obtained only by your auxiliaries.

The following information is required; it should be lettered with the answers in your drawing:

Length inclined eave line.................... ——— feet
Length short hip........................... ——— feet
Length long hip ....——— feet
True angle between inclined eaves and short hip..——— °-′
True angle between inclined eaves and long hip...——— °-′
Area skew portion of the roof.................. ——— sq. ft.
Length of the pole strut (perpendicular to roof).— —— feet
Angle between the strut and the pole............——— °-′

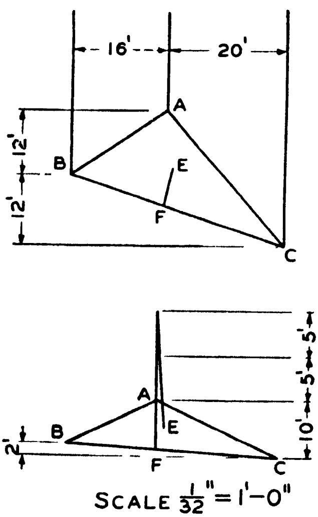


Fig. 14*f*.—Part of a roof.

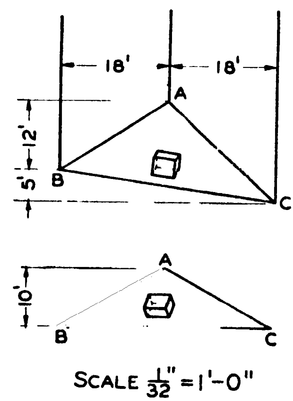


Fig. 14*g*.—Part of a roof with a skylight.

Sheet 14-5 (Fig. 14*g*)

In Fig. 14*g* there is shown the plan and front view of a part of a roof. Copy these two views at a scale of $\frac{1}{16}'' = 1'\text{-}0''$. It is desirable to add a skylight $4'\text{-}0'' \times 4'\text{-}0'' \times 2'\text{-}0''$ high, perpendicular to the roof with one side parallel to the nearest eaves, distant 3 feet in the clear. Draw first and second auxiliary, put the skylight on these two views, and then from this data place the skylight upon the plan and front view in its proper position.

It is better here if the second auxiliary is placed opposite the first.

This is the end of Lesson 14. It has been a hard lesson but a mastery of its principles is essential if one wishes to do advanced design.

LESSON 15

THE LINE VIEW

The line view is really a special case of the double auxiliary. However, instead of looking squarely at a surface, we look along a line, and to get the necessary quantities for the view along the line we must also look squarely at it. Or, in other words, we must project the line upon a plane

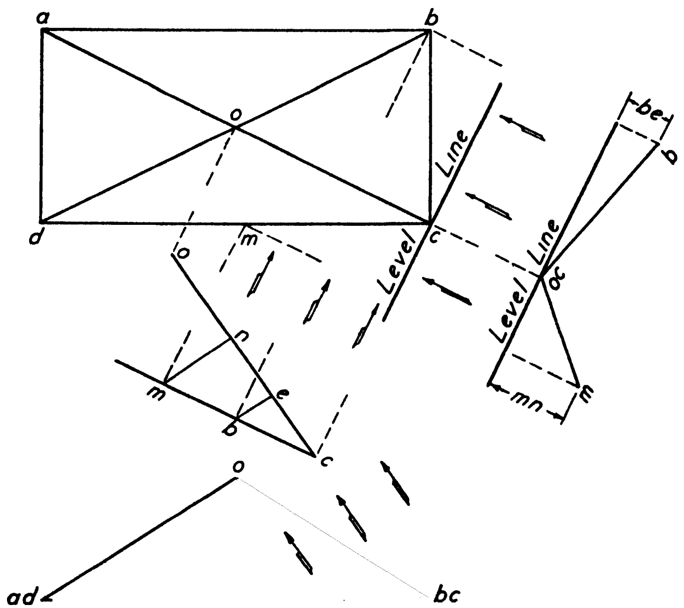


FIG. 15a.—A line view of a pyramid.

perpendicular to it and also parallel to it. These views or projections in many ways are similar to those in the two preceding lessons.

There are three practical reasons for the use of the line view:

All dimensions perpendicular to the line are shown in their true size.

All angles between planes for which the line is the intersection are shown in their actual size.

The view along the center line of a pipe or similar object shows a section of the object in its true size and shape.

Let us now consider a pyramid with a rectangular base as shown in Fig. 15a. It is required to find the angle between the faces at the hip lines,

oa, *ob*, *oc*, and *od*. As they are all alike, we will merely find the angle at one of them, *oc*.

The first step is to draw at some point a level line through the line *oc*. Then construct a single auxiliary view, looking always parallel to the level line. This is shown between the top and front views. Note that the angle *ocb* in the first auxiliary is the angle between the hip and the horizontal.

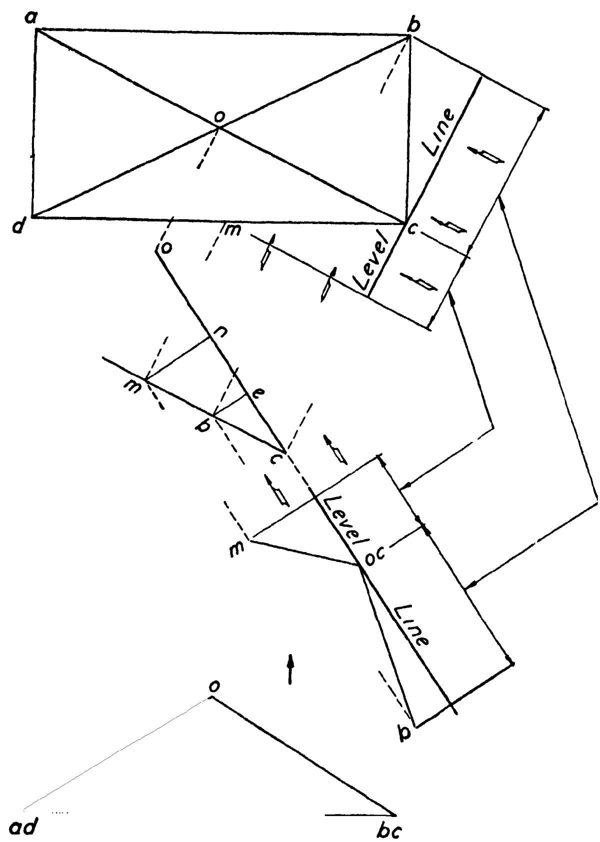


FIG. 15b.—Another method of getting a line view.

It is required to get the angle between the planes *boc* and *doc*. Then in addition to the line, we must show a point in each adjacent plane; we have chosen *b* and *m* as such points. To locate them in the first auxiliary, note that they are points in the eaves and hence must be shown at the level of the eaves.

The direction of the view in the two auxiliaries is shown by the arrows. In the first auxiliary *m* will be a distance *mn* below the line; this is the real distance and hence must appear on the second auxiliary; *m* will then be

opposite *m* in the top view and located a distance *mn* below the level line in the second auxiliary. The point *b* is located similarly. Then the angle *mob* is the required angle between the planes *boc* and *doc*.

The location of the base line for the first auxiliary and the level line for the second auxiliary is determined merely by the necessity of keeping the views a proper distance apart.

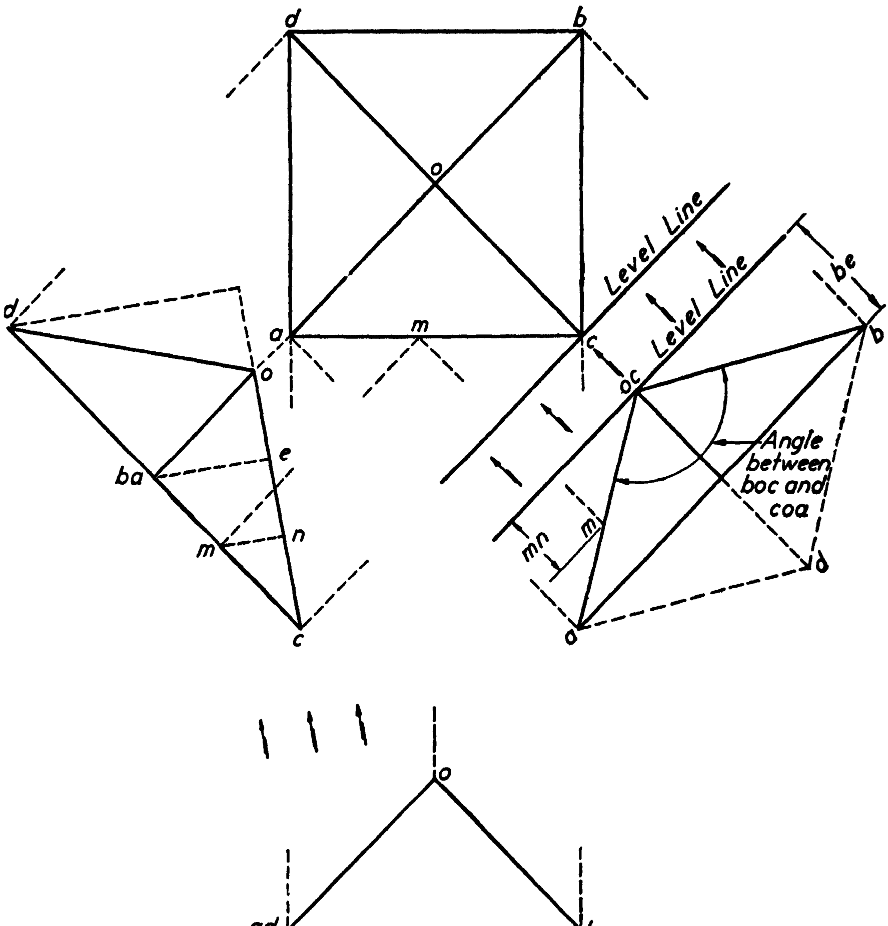


FIG. 15*c*.—A complete line view.

Figure 15*b* shows the second auxiliary placed opposite the first auxiliary. This last-named treatment may be employed but it does not seem so clear to the workman. In Fig. 15*c* we have added dotted lines showing another complete object in a line view.

REQUIRED WORK: LESSON 15

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

15-1. Explain the line view.

15-2. How can one see the true size of the angle between two planes?

15-3. Why is it true that the cross section is correctly shown when one looks along the center line?

15-4. Two lines are perpendicular in space. How must the view be taken to show one of them in its true size?

15-5. Is the height of the pyramid shown at its true size in the first auxiliary?

15-6. Is this height shown in its true size in the second auxiliary?

15-7. Will all angles between the hips and the horizontal be alike?

15-8. Is *oc* in the top view the true length of the hip?

15-9. How would you get the true value of the angle *aod*?

15-10. Would the answer be changed in Fig. 15*a* if points other than *b* and *m* are taken in the two adjacent eaves?

15-11. Is it allowable in obtaining angle at *oc* to take points in the eaves of the faces *oad* and *oab*?

15-12. Will the sum of the angles in the faces of the pyramid at *o* be more or less than 360°?

15-13. By changing the height of the pyramid, the values of the angles between the faces can be changed. What are the limiting values of these angles?

15-14. In the roof surface of *abc*, a point not in the eaves but in the face *abc* is known and is used in the solution. Outline how it will be projected and measured.

15-15. Would the answer then be correct?

15-16. State relative value of the two angles between the planes at the two lower hips.

Sketches

15-17, 15-18, 15-19, 15-20. Sketch the required views for sheets 15-1, 15-2, 15-3, 15-4, and 15-5, omitting the sheet that you draw.

LETTERING

Letter in capitals and small letters.

PAINT RED LEAD

The first letter in each word is to be in caps; other letters should be lower case. Use the lettering table in Lesson 14 to make the first copy in vertical and inclined lettering, in which first letters and *b*, *d*, etc., are ¼″ high. Then copy these as nearly as you can by eye, first 3⁄16″ high, then ⅛″ high.

SHEETS

All sheets are to be in pencil on pencil cloth and are to be dimensioned. Be careful to show clearly just how each quantity is obtained.

SHEET 15-1

A masonry footing is symmetrical about two vertical planes. The lower portion is 4′-0″ × 6′-0″ × 1′-0″ high. From this it slopes to a top 3′-0″ higher, which is 1′-4″ × 2′-0″. The 4′-0″ dimension slopes to 1′-4″ and the 6′-0″ to 2′-0″.

Draw first and second auxiliaries, both complete, looking along a sloping edge line. Scale ½″ = 1′-0″.

SHEET 15-2

A mine surveyor's notes contain the following information:

	North	East	Elev.
A	2754.2	1755.8	1204.0
B	2836.3	1831.2	1173.6
C	2877.4	1817.4	1208.7
D	2858.0	1750.0	1187.0

Plot at a scale of 1/32″ = 1′-0″, find the shortest distance between *AC* and *BD*, and plot this shortest distance.

Select a certain spot on your drawing and call this, let us say, North 2800 and East 1800. Then you can readily plot the points *A*, *B*, *C*, and *D*, calling north the top of the sheet. Also select below, a certain line as Elevation 1200. Then the front view is readily made.

The shortest distance between two lines must be perpendicular to each. Hence if we draw a line view of either *AC* or *BD*, the shortest distance will appear as a perpendicular from the other line to the line that shows as a point. Draw then the first and second auxiliaries of *AC*, resulting in a view which shows *AC* as a point. The perpendicular from this point to *BD* represents the desired distance.

Let *F* represent the *BD* end of the perpendicular. This can readily be projected back to *BD* in plan, front view, and first auxiliary. The other end *E* may be located in the first auxiliary in which *EF* is perpendicular to *AC*. (A perpendicular let fall to a line at which you are looking squarely always appears as a perpendicular.)

SHEET 15-3 (Fig. 15*d*)

In the roof as shown in Fig. 15*d*, let *cn* be north. Then *b* is 12 feet south of, 18′ west of, and 10 feet below *a*. *c* is 17′ south of, 18′ east of and 10′ below *a*. Find the angle on the line *ac* between the two adjacent roof areas. Scale 1/16″ = 1′-0″. Copy cut; draw front view, top view, and the two auxiliaries.

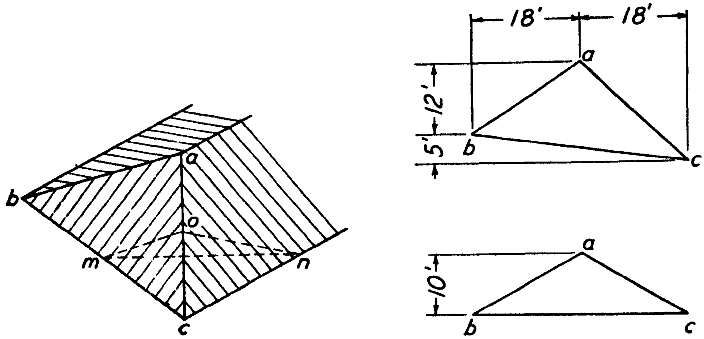


FIG. 15d.—Part of a roof.

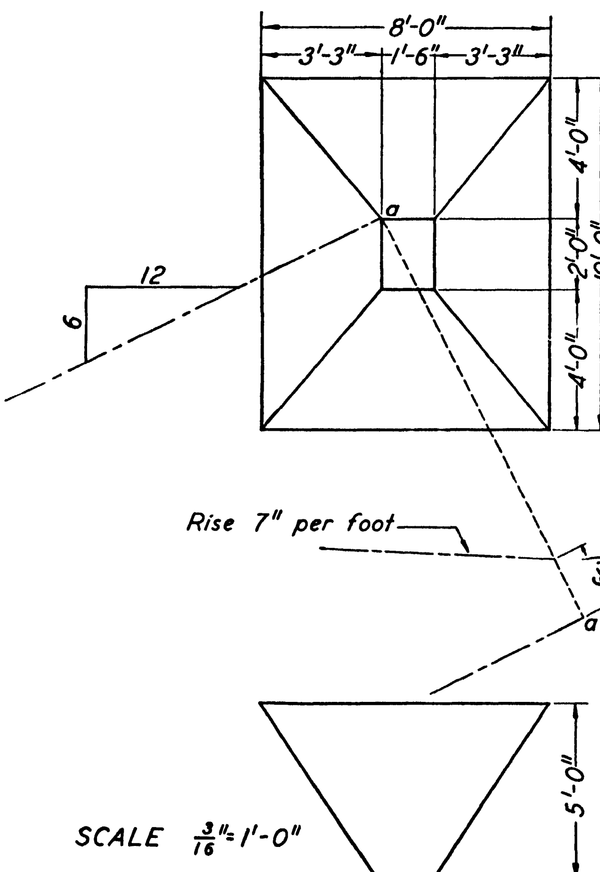


FIG. 15e.—A hopper with connecting chute.

Sheet 15-4 (Fig. 15*e*)

Figure 15*e* shows a hopper with the center of a rectangular enclosed chute connecting to it. The sides of the chute are vertical.

Draw at a scale of 3/8″ = 1′-0″ top and front view of hopper and chute combined, and first and second auxiliaries of chute alone.

Draw top and front view, including in each the center line of the chute. Then construct the first and second auxiliary in the usual manner. In the latter, the view of the line will be of course a point. Construct about this point as a center the section, a rectangular area 12″ × 24″ with the 12″ parallel to the base of the first auxiliary. In the first auxiliary, looking always parallel to a level line, the height of the chute will be, of course, 12″; also the length will be shown there in its true size. Now the lower end of the chute can be projected from the front view to the top view and thence to the first auxiliary. The sides of the chute are parallel to the center line in space; hence, they must be parallel in all views.

Sheet 15-5

Beneath the hopper of Sheet 12-5 is a valve 8′-0″ from the wall, 12′-0″ from the edge of the platform, and 1′-0″ above the floor and also a cap 10′-0″ from the wall, 5′-0″ from the edge of the platform, and 5′-0″ above the floor.

Find the shortest distance between the hopper and a straight pipe connecting with the valve. Draw a line view of the valley in the hopper which is nearest the pipe. In this the perpendicular to the pipe between the pipe and the valley is the correct answer.

The scale is 1/4″ = 1′-0″.

This is the end of Lesson 15 and of the important subject of auxiliaries. It is an excellent time for another review.

LESSON 16

SIMPLE REVOLUTION

In revolution, the observer keeps the usual viewpoints but the object itself is turned. Simple revolution will consider only three directions for the axis of rotation:

Vertical.
Directly front to back called the front axis.
Perpendicular to the other two called the side axis.

When an object is revolved about a vertical axis, the top view is turned through the given angle without other change. If desired, one may make a

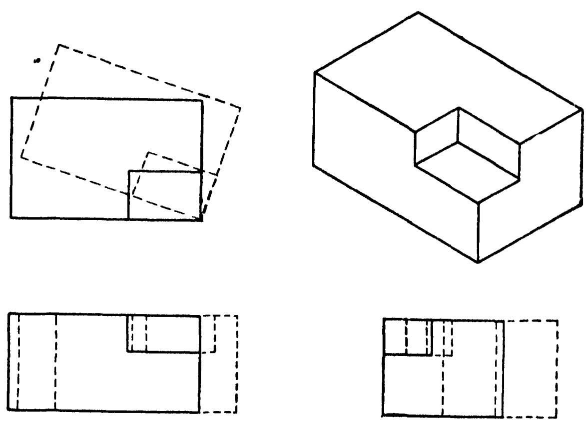


FIG. 16*a*.

tracing of the old view, turn through the required angle and then copy. In both the front and the side view the heights will not be altered by the revolution and distances horizontally are determined by the usual rules of projection. In Fig. 16*a* the object in the original position is shown by full lines while the revolved portion is indicated by light dotted lines.

When an object is revolved about a front axis, the front view is turned through the given angle without other change. In the top view the points stay the same distance from the front but are moved horizontally to remain over the corresponding points in the revolved front view. In the side view the points still stay the same distance from the front but are opposite their

position in the revolved front view. The object revolved about a vertical axis in Fig. 16*a* is revolved about a front axis in Fig. 16*b*.

When an object is revolved about a side axis, the side view is turned through the given angle without other change. In the front view all points

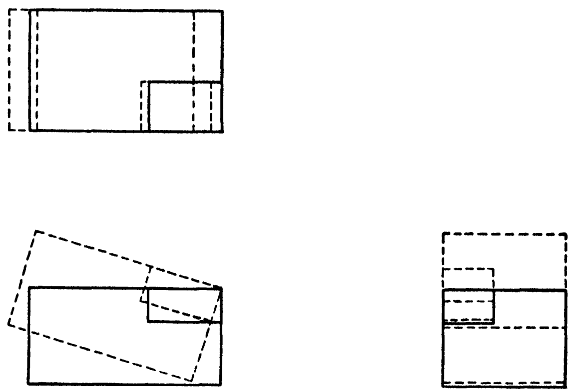


FIG. 16*b*.—Object in Fig. 16*a* revolved again.

remain in the same vertical line as formerly, but horizontally opposite the revolved position as shown in the side view. Likewise in the top view objects do not move horizontally, their position front or back being made to correspond with the revolved side view. The object we have revolved twice about other axes is shown in Fig. 16*c*, revolved about a side axis.

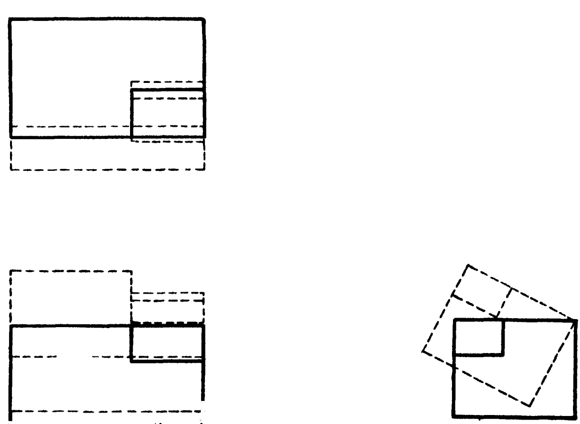


FIG. 16*c*.—Object of Fig. 16*a* revolved again.

As will be seen the views are different for different directions of the axis of rotation but they follow the same rules whatever the position of the center may be. Also views vary somewhat with the amount of rotation, even for the same direction of the axis.

Lettering the corners will assist in working out this type of problem. However, it tends to get you in the habit of revolving letters rather than objects and it tends to mechanize the work. You may be helped a great deal by the fact that lines connecting in space connect in each view, and lines parallel in space are likewise parallel in each view.

The work in revolution should be compared with that in auxiliary views. The two are much alike: in the auxiliary, we move our viewpoint; in revolution, we move the object. In both cases, we are looking squarely at the skew face for which we need measurements. Simple revolution in particular is quite similar to the first auxiliary.

REQUIRED WORK: LESSON 16

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

16-1. About what axes may simple revolution occur?

16-2. Compare the single auxiliary with simple revolution.

16-3. When an object is revolved about a vertical axis, what change occurs in the front view?

16-4. An object is turned about a side axis; state the changes in the top view.

Sheet 16-1

16-5. Suppose the lot was 200 feet long rather than 180 and other quantities were unchanged. What per cent would this increase the amount of coal?

16-6. How would the amount of the coal be affected if the strike were changed?

Sheet 16-2

16-7. Would a circular chimney of 7′-0″ external diameter cut out more or less area?

16-8. If the pitch of the roof were 45° instead of 30° would the hole be larger or smaller?

16-9. Does the distance of the chimney from the eaves affect the answer to the preceding question?

Sheet 16-3 (Fig. 16*d*)

16-10. Obtain the approximate length of the belt.

16-11. State angle (so many inches vertical to 12″ horizontal) of inclination of the center line of pulleys to the horizontal.

Sheet 16-4 (Fig. 16*e*)

16-12. How long are the legs of this table?

16-13. If the braces for the legs are merely nailed, what is their length on the short side?

16-14. Write the order for the lumber for this table.

Sheet 16-5

16-15. Which two sides of the truncated pyramid will have the higher point?

16-16. Which is the longest, *oa*, *ob*, or *oc?*

Sketches

16-17, 16-18, 16-19, 16-20. Sketch the required views for Sheets 16-1, 16-2, 16-3, 16-4, and 16-5, omitting the sheet that you draw.

LETTERING

Letter in capitals both vertical and inclined.

RED RIVER BRIDGE

Make in extended lettering, that is, spread out. Increase the width and spaces of all letters (except I) by 25%. Do this for the ¼″ height and then copy as closely as you can for the heights of 3⁄16″ and ⅛″.

SHEETS

All sheets are to be in pencil upon vellum.

Sheet 16-1

A rectangular lot is 64 by 180 feet and is underlain by anthracite coal 5 feet thick weighing 96 lb. per cu. ft. The strike N 42° W makes an angle of 60° with the length of the property, and the dip is 22°-30′. How much coal is there in tons of 2240 lb.? Scale 1″ = 32′-0″.

Note: The strike is the angle of a level line.

The dip is the diedral angle between the vein and the horizontal.

Draw area as the front view with the strike horizontal and show the dip in side view. Then rotate lot through dip to get the real area of vein.

Sheet 16-2

An octagonal chimney is 5′-0″ in inside diameter between flats; the brickwork is 12″ thick. Obtain the true size of the hole in a roof necessary for this chimney if the pitch of the roof running in the direction of the flat sides of the chimney is 30° with the horizontal. Consider that the strip of the roof is 5 feet to one side of the center of the chimney and 6 feet to the other side. Locate the center of the chimney 6′-6″ from the edge of the building and 8′-0″ from the edge of the roof. Scale ¼″ = 1′-0″.

Draw the plan and the front view; revolve the hole so that its true size is seen in the revolved top view.

Sheet 16-3 (Fig. 16*d*)

A 16″ diameter pulley is connected to a 48″ diameter pulley by a continuous belt. The pulleys are 21′-0″ apart horizontally and the larger pulley is 8′-0″ above the smaller.

Draw top and front view with the plane of pulleys perpendicular to the

front view. Then revolve the top view 20° and draw the corresponding front view. Scale ¼″ = 1′-0″.

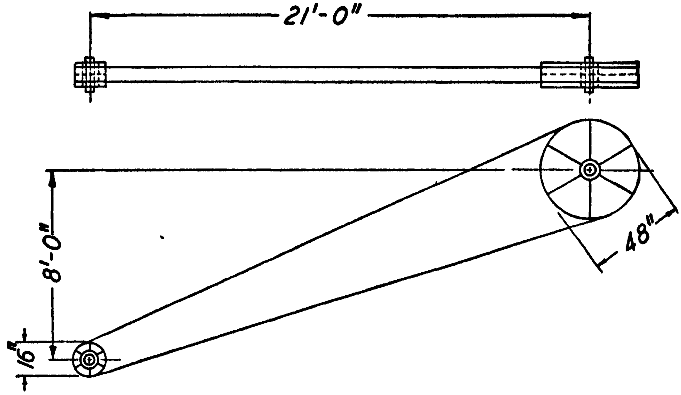


FIG. 16*d*.—Two pulleys connected by a belt.

SHEET 16-4 (Fig. 16*e*)

In the upper part of the drawing, copy the three views of the table shown in Fig. 16*e*. In the lower part, draw the same views when top view is revolved 30° clockwise. The scale is ¾″ = 1′-0″.

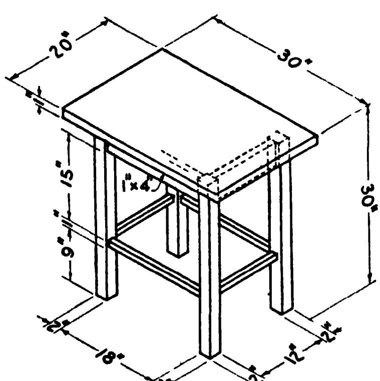


FIG. 16*e*.—A table.

SHEET 16-5

The truncated pyramid *oabc* has a base *abc* which is a right triangle. The leg *ab* is 24″ and *bc* is 20″. Before the vertex was cut away, it was 18″ vertically above the base at a point 7″ from *ab* and 6″ from *bc*. The line *oa* is cut off at a height of 14″; *ob* at 13″; and *oc* at 10″. Draw front, top, and right side views at a scale 1½″ = 1′-0″.

Next revolve the sides *oab*, *obc*, and *oac* as has been done in Sheet 14-2 and as illustrated in Fig. 14*c*. This method is really more revolution than auxiliary. The slant height of the various points in *oab* and *obc* can be obtained from front or side views. For the face *oac* we may use the fact that the length *oa* is in its true length in every development in which it is shown; hence, it must be equal in both. The same reasoning applies, of course, in the case of *oc*.

We have now reached the end of Lesson 16. Further developments in revolution will be taken up in the next lesson.

LESSON 17

DOUBLE REVOLUTION

A line in any direction can be revolved to any other direction in two simple revolutions. For example, the first direction may be turned in plan until it is above or below the second. Then a turn in the side view causes the two directions to coincide. This combined operation is called a double revolution. In this way we can turn any surface, no matter what oblique angle the surface originally made with the usual direction of view, so that the surface is seen in its true size in some view.

The methods used are the same as in the preceding lesson, only they are applied twice. For example, in Fig. 17*a* are shown the top view, the front

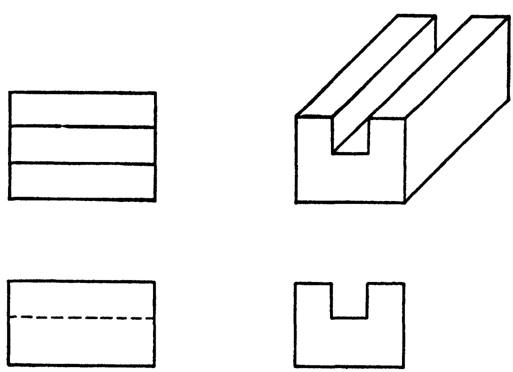


Fig. 17*a*.

view, the right side view, and a pictorial drawing of a notched block. Figure 17*b* shows the same views of the same block when the top view has been rotated clockwise 15°. Follow this through carefully as a review of Lesson 16. Then, in Fig. 17*c*, the front view of Fig. 17*b* is rotated clockwise 15° and the other views changed accordingly. This is now a double revolution.

Finally let the right side view in Fig. 17*b* be rotated clockwise 15° and the other views changed to correspond and we have the views shown in Fig. 17*d*.

Let us now take the same block and the same views as shown in Fig. 17*e* and let it be required to revolve the block so that we are looking along the line *ab*.

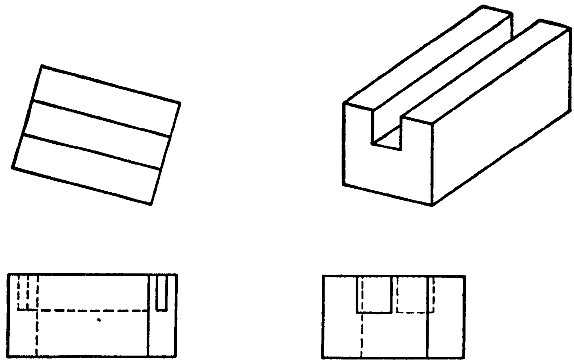


FIG. 17b.—The block of Fig. 17a once revolved.

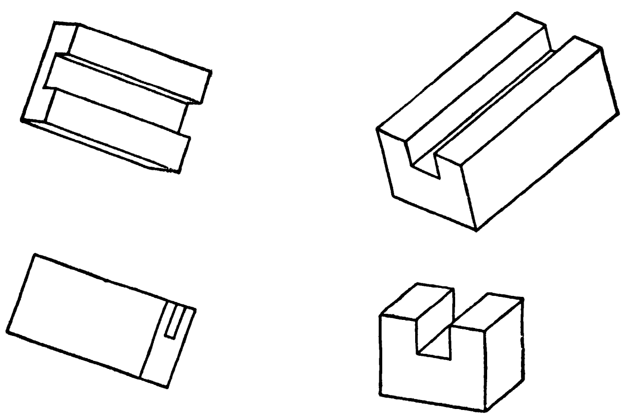


FIG. 17c.—The block of Fig. 17a twice revolved.

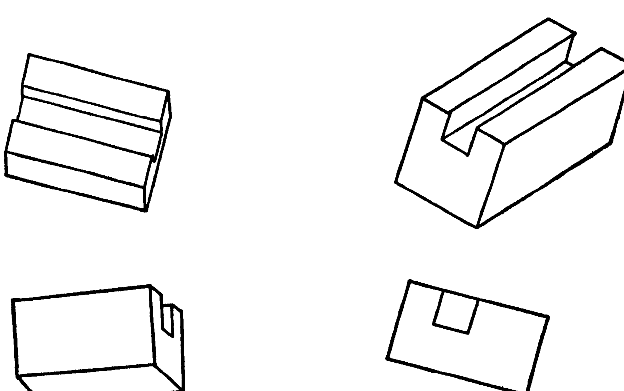


FIG. 17d.—The block of Fig. 17a twice revolved.

First, as shown in Fig. 17*f*, revolve the block so that *a* and *b* are in the same vertical line in the plan; then draw the corresponding views. Next

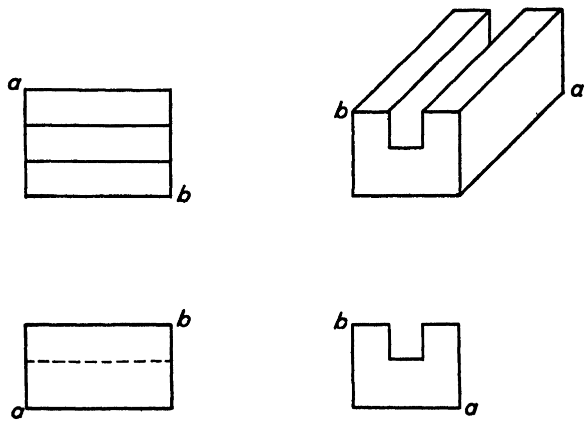


FIG. 17*e*.—The block of Fig. 17*a* again.

revolve the side view taken from Fig. 17*f* so that *a* and *b* are the same height. Then in the front view of Fig. 17*g*, we have the required view with *a* and *b* in line; *ab* is now in its true length in top and side views.

In revolution it is usually required to show some face in its true size. Time can then be saved by dealing only with that face. For example, the

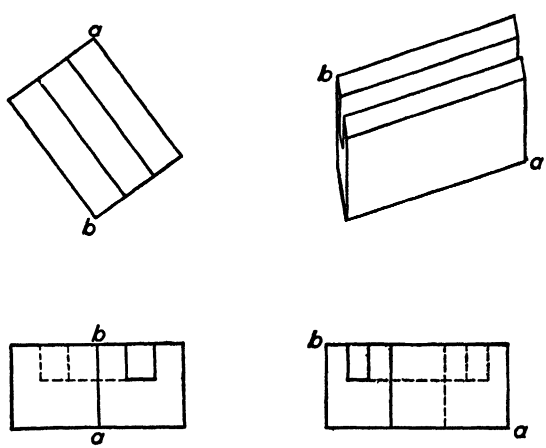


FIG. 17*f*.—The block of Figs. 17*a* and 17*e* once revolved.

true size of the skew face of the truncated prism in Fig. 17*h* can be obtained by determining the real size of the triangle shown by the three views in Fig. 17*i* as *abc*.

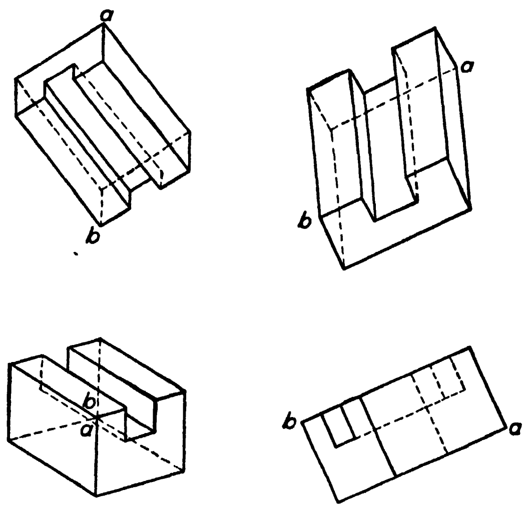


FIG. 17*g*.—The block of Figs. 17*a* and 17*e* revolved a second time.

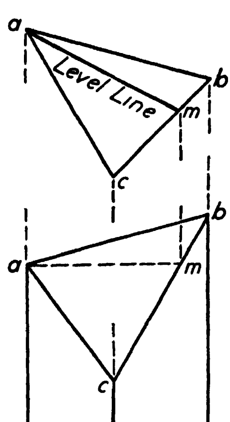


FIG. 17*h*.—A truncated prism.

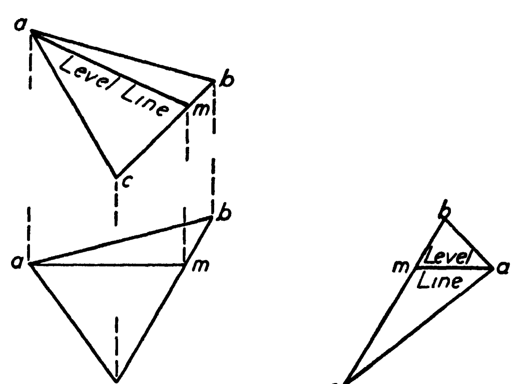


FIG. 17*i*.—The skew face of the truncated prism of Fig. 17*h*.

Next, let us locate the level line *am* and revolve the triangle *abc* in the top view until *am* is horizontal as in Fig. 17*j*. In the front and the side views, points will still be in the same horizontal line but their positions to the right or left will be changed to correspond with the altered top view.

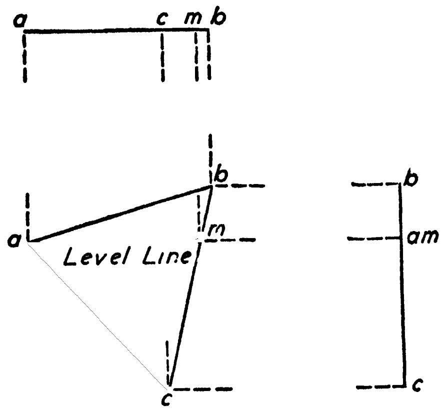


FIG. 17*j*.—The skew face once revolved.

Finally, turn the right side view in Fig. 17*j* so it is upright as in Fig. 17*k*. The side view will not be changed except for its rotation. The points in the front and top will not move to the right or left, but their position up and down the sheet will be changed to correspond to the altered side view. Then the corresponding front view is the true size of the area, *abc*.

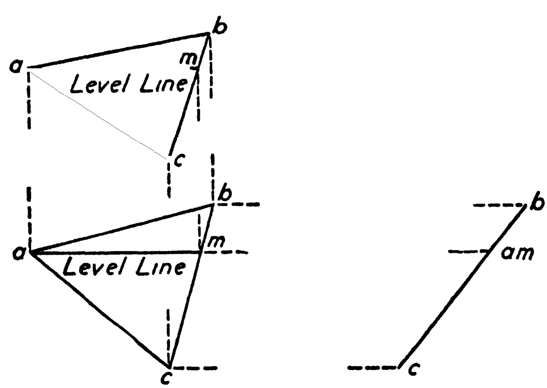


FIG. 17*k*.—The skew face twice revolved.

So far as the writer knows, all industrial problems in drawing may be solved by auxiliary views and also by revolution. Usually a double revolution is enough even in complicated cases.

REQUIRED WORK: LESSON 17

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

17-1. Define double revolution.

17-2. A level line going N 10° E is to be revolved until it has a direction of N 10° W and an elevation of 45°. How would you revolve it?

17-3. Will the order in which the views are revolved have any effect on the final result if the angles are unchanged?

17-4. Compare auxiliary views with revolutions.

Sheet 17-1

17-5. Compute the contents of this footing in cubic feet.

Note: The volume of a pyramid is equal to the area of the base times one-third of the altitude. The volume of a truncated pyramid equals the volume of the original pyramid minus the volume of the part cut away.

Sheet 17-2 (Fig. 17*o*)

17-6. What is the value of the four reentrant angles in this V block?

17-7. Compute the area of the cross section.

Note: This is most easily done by finding the area of the whole and subtracting the areas of the four V's.

Sheet 17-3 (Fig. 17*p*)

17-8. How far is it in the clear between the wedge-shaped supports?

17-9. Compute the area of the cross section between supports.

Sheet 17-4 (Fig. 17*q*)

17-10. What size rivets are used here?

Note: The common sizes are ½", ⅝", ¾", ⅞", etc.

17-11. Compute the weight of this angle.

Note: Steel weighs 0.28 lb. per cu. in.

Sheet 17-5 (Fig. 17*r*)

17-12. Which hip will be longer, *ac* or *ab*?

Indicate the solution by revolution to obtain the following required quantities:

17-13. The angle between the two pipes shown in Fig. 17*l*.

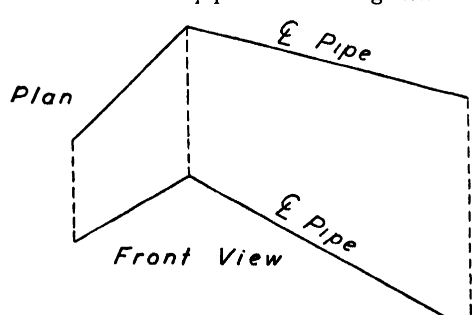


Fig. 17*l*.—The angle between two pipes.

17-14. The point where the center of a stay goes through a roof in Fig. 17*m*.
17-15. The angle *nmo* in the sloping roof of Fig. 17*m*.
17-16. The shortest distance between two electric wires, Fig. 17*n*.

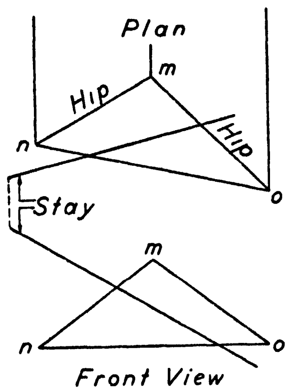


FIG. 17*m*.—A stay passing through a roof.

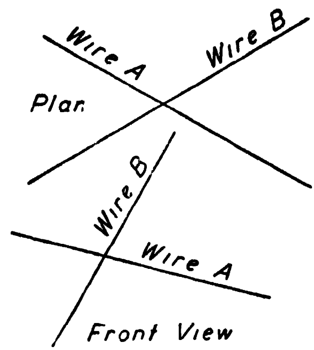


FIG. 17*n*.—Two electric wires.

Sketches

Sketch the solutions for

17-17. 17-13.
17-18. 17-14.
17-19. 17-15.
17-20. 17-16.

LETTERING

Letter "Must not exceed 2″" in small letters, both vertical and inclined. Decrease the width of the letters and the spacing between letters by 20%. Do this according to the table in Lesson 14 for the ¼″ height, then copy it as closely as you can for letters 3/16″ and ⅛″ high. These heights refer to capital letters and those like *b* and *d*.

SHEETS

All sheets are to be in pencil upon vellum. When a view is to be turned, copy it carefully on a small piece of vellum and then place underneath your finished sheet, being careful to turn through the required angle.

SHEET 17-1

The base of a footing is 6 feet east and west, 4 feet north and south, and 12″ high. From the top of this base it slopes gradually until at an elevation 3 feet higher the top is 2 feet east and west and 1′-4″ north and south. Scale

$\frac{3}{8}'' = 1'\text{-}0''$. Letter the northwest corner *a* at the top of the 12″ base and *b* at the extreme top.

Draw front, top, and right side views.

On these views draw in light dotted lines the same three views when *ab* is made north and south in plan.

Below draw front and right side views where *ab* is made horizontal as well as north and south.

Omit dimensions.

SHEET 17-2 (Fig. 17*o*)

In Fig. 17*o* is shown the top front and right side views of a V block.

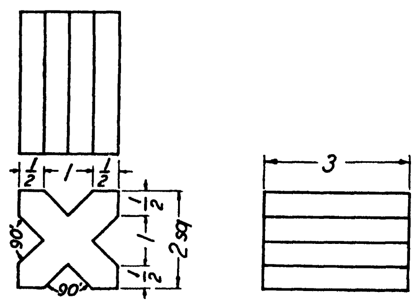


FIG. 17*o*.—A V block.

First copy views as shown with dimensions at a scale of $6'' = 1'\text{-}0''$. Then turn top view 15° counter-clockwise and draw the other two views. Finally turn the latter side view 15° clockwise and draw the other two views.

SHEET 17-3 (Fig. 17*p*)

In Fig. 17*p* is shown the top, front, and right side view of a bracket.

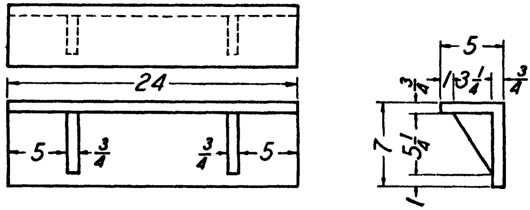


FIG. 17*p*.— A bracket.

First copy views as shown with dimensions. The scale is $1\frac{1}{2}'' = 1'\text{-}0''$. Then turn top view counter-clockwise 30° and draw the other two views without dimensions. Finally turn the right side view 30° clockwise and copy the other two views without dimensions.

Sheet 17-4 (Fig. 17q)

In Fig. 17q is drawn the front, top, and right side view of an angle.

First copy views as shown at a scale of $1\frac{1}{2}'' = 1'\text{-}0''$. Dimensions are to be inserted for these three views only. Then turn top view clockwise 30° and draw the two other views to correspond.

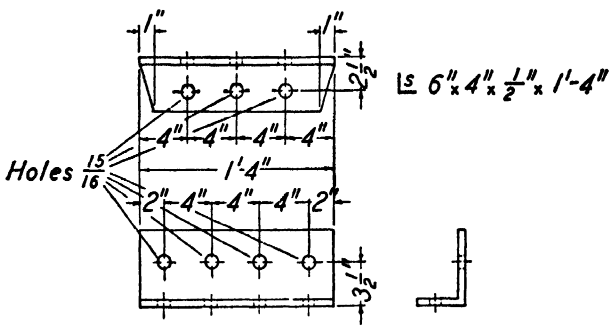


Fig. 17q.—An angle.

Finally turn the latter right side view 30° clockwise and draw the two other views to correspond.

Sheet 17-5 (Fig. 17r)

In Fig. 17r are shown three views of a skew hip roof. Copy this at a scale of $\frac{1}{16}'' = 1'\text{-}0''$. Dimension only this view.

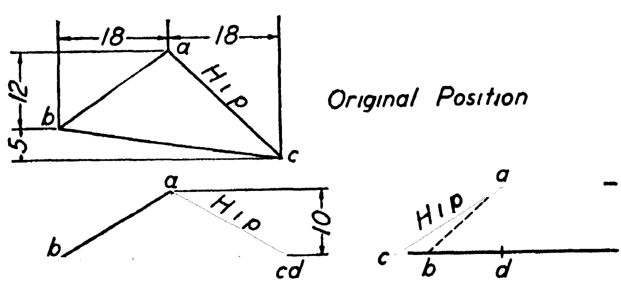


Fig. 17r.—A skew hip roof.

Turn in two revolutions so that *ca* becomes a point. When this has been done the view of the roof along a hip shows the true size of the angle between the two adjacent planes.

This is the end of Lesson 17. It is hoped that you now understand revolution so that you can solve many practical problems by its use.

LESSON 18

OBLIQUE DRAWINGS

In the oblique drawing, the front view is made exactly the same as in orthographic views. However, instead of showing depths on another view, we indicate them on the same view along inclined lines. For example, let it be required to make an oblique drawing of the object indicated by its three orthographic views in Figs. 18*a*, 18*b*, and 18*c*. Lay out first $a'b'c'd'e'f'$, making it the same as *abcdef* in Fig. 18*b*. We next choose the angle at

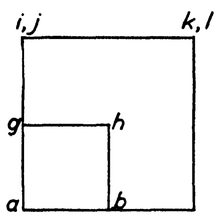


FIG. 18*a*.

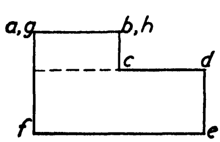


FIG. 18*b*.

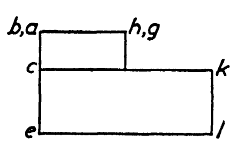


FIG. 18*c*.

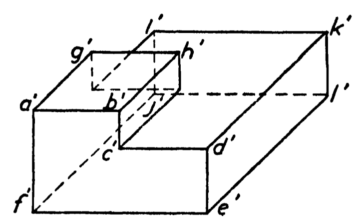


FIG. 18*d*.

which the depths are shown; the angle is often made 45 degrees with the horizontal and we will use that value here. The length $a'g' = b'h'$ is made equal to ag and laid out along these 45-degree lines. The points on the lower portion are now laid off, $d'k' = e'l' = f'j' = ai$ on Fig. 18*d*. The drawing may now be readily completed.

There are a number of important principles:

Vertical lines are drawn vertically.

Lines that are parallel in the object are parallel in the oblique.

Distances and angles in the front plane or planes parallel to it are shown in their true size. If the drawing has been made at a reduced size, the angles are still at their actual value, while the length of any line is reduced in the same proportion. In other words, we use the same methods

in constructing a face in one of these planes that we employ in making the orthographic view of that same face.

Distances perpendicular to the front plane are shown in their true (or proportional) size along the diagonal lines.

Suppose, now, that it is required to make an oblique drawing of a rectangular solid with its back cut off at an angle of 35 degrees with the base, that is, 55 degrees with the vertical. Make first an oblique drawing of the block as though it were solid as in Fig. 18*e*. Next, using the vertical height, *ab*, as a leg, lay out the right triangle *abc*, making the angle *bac* equal to 55 degrees. Then *bc* equals the offset perpendicular to the back face and it is laid off from *b* to *d*.

If there is a circle in the face that is shown in the front view or a face parallel to it, proceed as in orthographic projection.

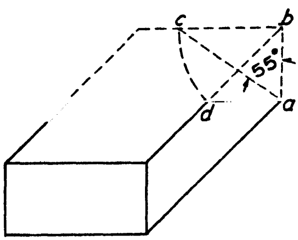


FIG. 18*e*.

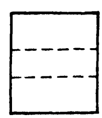


FIG. 18*f*.

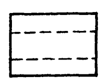


FIG. 18*g*.

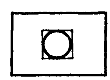


FIG. 18*h*.

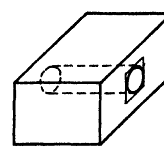


FIG. 18*i*.

If a circle is in a side face, we first "box" the circle. That is, in the orthographic view, we draw horizontal and vertical lines around the circle, "boxing" it in. For example, let us consider the block shown in its orthographic views in Figs. 18*f*, 18*g*, and 18*h*. Here Fig. 18*h* shows the circle with its boxing. Then, as in Fig. 18*i*, draw the oblique view of the solid including the boxing lines. Finally draw a curved line so that it is tangent to (just touches) the boxing lines at the center of each of those lines. The boxing lines should now be removed.

The methods given hold only for angles and circles seen in their true size in one of the side views. For angles and circles that are seen obliquely or for irregular curves, select important points; two are enough for a line, but several are needed for a curve. Then for each point, with respect to a selected reference point:

Determine:	Lay off:
Its distance up or down.	That distance as in an ordinary view.
Its distance to the right or left.	That distance as in an ordinary view.
Its distance front or back.	That distance front or back along the chosen angle.

It might seem that these instructions were not needed for sketching. However, they will be found quite valuable. There are many lines that will not look right until the student has taken the pains to establish points by the method indicated. It is true that distances will have to be estimated, but these distances can be estimated far better than can certain angles and curvatures.

The angle at which depths are shown may be 30°, 45°, 60°, or any desired value. The depths may extend above to the right, above to the left, below to the right, or below to the left. When an angle is below, it shows the bottom of the object; a drawing made this way is said to have "reversed axes."

Any face can be chosen for a front view; usually the most complicated one is selected because it makes the work much easier. Thus, if Fig. 18*h* had been chosen as a front, it could have been drawn much more quickly because then the hole would have been represented by a true circle. However, the principal idea in selecting both the front and the angle is to choose them so that the object is shown to the best possible advantage.

An oblique drawing may be scaled only in its front face, in faces parallel to it, or in depths parallel to the chosen angle.

In dimensioning an object in the oblique, we follow in general the rules for orthographic drawings. Extra caution is necessary to show just what the limits are. If practicable, place the extension lines in the prolongation of lines on the drawing. The guide lines for the lettering should be parallel to the corresponding dimension line, and the slope of the numbers should be parallel to the corresponding extension lines.

Oblique drawings are excellent in giving an idea of what an object is like. However, they are not as easy to read exactly, and there is great danger that the dimensions may be misunderstood.

REQUIRED WORK: LESSON 18

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

18-1. What is the principal difference between orthographic views and oblique views?

18-2. How is a circle drawn that is in the front plane?

18-3. How is a circle drawn that is in the side plane?

18-4. Explain how an angle in the side plane is laid out.

Sheet 18-1 (Fig. 18*k*)

18-5. If the smaller pulley is making 280 RPM, how many RPM (revolutions per minute) is the larger pulley making when the belt is placed as shown?

18-6. Answer question **18-5** if belt is shifted to the largest diameter on the lower pulley and the smallest diameter on the upper pulley.

18-7. What should be the length of this belt?

SHEET 18-3 (Fig. 18*l*)

18-8. How many diagonals are there in the four sides of this tower?
18-9. State the length of the horizontal members in the sides 28 feet up.
18-10. What is the length of the member *cc'*?

SHEET 18-4

18-11. How is the tool held in the tool holder?
18-12. State the distance apart *c/c* of the two set screws.
18-13. Could a tool whose cross section was $\frac{7}{16}''$ square be used?

SHEET 18-5 (Fig. 6*j*)

18-14. What fixture is used at the given numbers: 4?
18-15. 10?
18-16. 12?

Sketches

Sketch an oblique view of the object shown in:

18-17. Fig 7*b*.
18-18. Fig. 13*a*.
18-19. Fig. 10*j*. Omit marks. Show entire bridge.
18-20. Fig. 10*d*. Show both right and left girders.

LETTERING

Copy the bill of material shown in Fig. 18*j* and also work the same out in vertical letters.

BILL OF MATERIAL FOR PIPE VISE			
Pce	Name	Q	Material
B	BASE	1	M S
Y	YOKE	1	ST DROP FORG
D	DOG	1	ST DROP FORG
SC	SCREW 11 THD PER IN	1	STEEL
H	HANDLE	1	STEEL
S1	SCREW 18 THD PER IN	2	STEEL
S2	SCREW 20 THD PER IN	2	STEEL
S3	SCREW 18 THD PER IN	3	STEEL
S4	SCREW 20 THD PER IN	2	STEEL
J1	JAW	1	HARD TOOL ST
J2	JAW	1	HARD TOOL ST
JH	JAW HOLDER	2	ST DROP FORG

FIG. 18*j*.

SHEETS

All sheets are in ink upon tracing cloth.

Sheet 18-1 (Fig. 18*k*)

Make an oblique drawing of this belt with its two pulleys. It is much easier and clearer if you keep the planes of the pulleys parallel to the front face. Scale 1″ = 1′-0″.

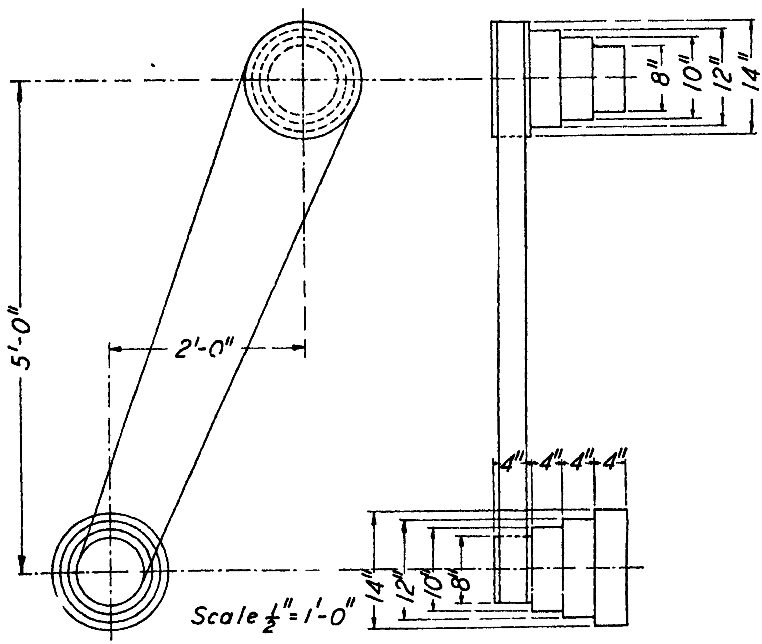


Fig. 18*k*.—Two pulleys connected by a belt.

Sheet 18-2

Place an oblique drawing of the guyed derrick of Sheet 12-2 in the upper part of your sheet. Scale 1″ = 32′-0″. Mark bearings and elevations for each point.

Place below an oblique drawing of the footing in Sheet 4-1. Scale ½″ = 1′-0″. Give the necessary dimensions.

Sheet 18-3 (Fig. 18*l*)

Make an oblique drawing of the tower shown in Fig. 18*l*. Scale ⅛″ = 1′-0″. Dimensions may be omitted.

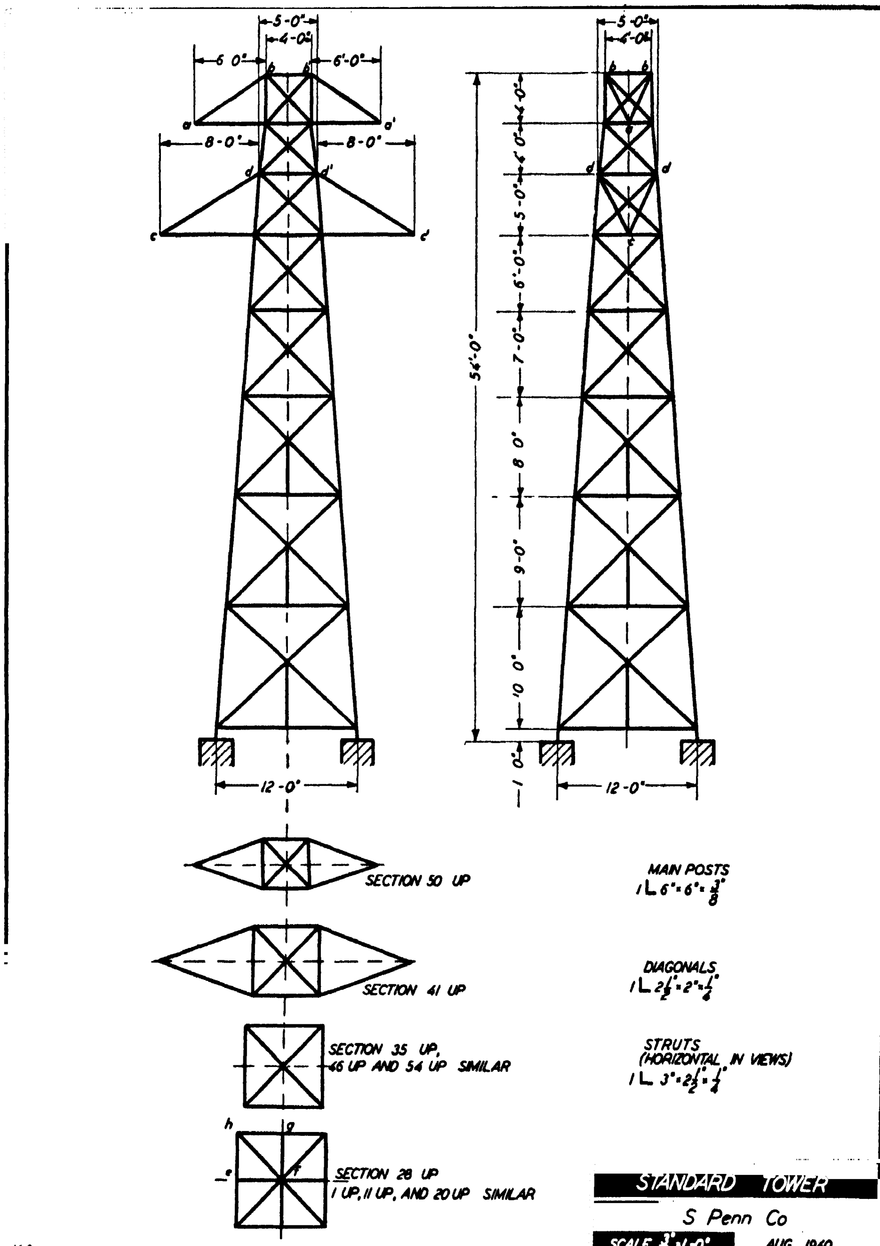

5-0"
4-0"
6 0"
6'-0"
8-0"
8-0"
12-0"
54'-0"
4-0"
4' 0"
5-0"
6'-0"
7-0"
8 0"
9-0"
10 0"
1 0"
12-0"
SECTION 50 UP
SECTION 41 UP
SECTION 35 UP,
46 UP AND 54 UP SIMILAR
SECTION 28 UP
1 UP, 11 UP, AND 20 UP SIMILAR
MAIN POSTS
DIAGONALS
STRUTS
(HORIZONTAL IN VIEWS)
STANDARD TOWER
S Penn Co
AUG 1940
KG

FIG. 18*l*.

Sheet 18-4 (Fig. 18*m*)

In the lower part of the drawing, place the top and the front view of the tool holder and above it put an oblique drawing of the same. All are to be full size and completely dimensioned.

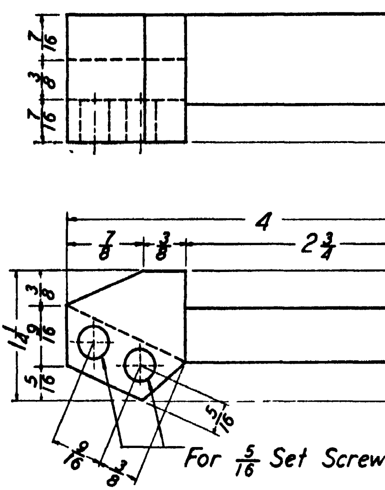


Fig. 18*m*.

Sheet 18-5

Make an oblique drawing of the pipes represented by orthographic views in Fig. 6*j*. This is diagrammatic, hence there is no scale. Separate the various parts, however, so that they show up clearly. Letter upon the drawing the given numbers and also the fixtures corresponding to those numbers. See text in connection with Fig. 6*j* for a description of the various accessories to plain pipe.

This is the end of Lesson 18. This is a very interesting subject; probably the pictorial drawings that you have used have already familiarized you somewhat with the subject.

LESSON 19

ISOMETRIC DRAWINGS

The isometric drawing is somewhat similar to the oblique in that it resembles a skew view. Like the oblique, vertical distances are measured vertically. However, there are some differences. Distances to the right or left in orthographic or oblique views are laid out to the right or left along lines sloping upward at an angle of 30° with the horizontal. Distances front or back are measured to the right or left along lines sloping to the right at angles of 30° with the horizontal. In this way the oblique drawing, Fig. 18*d*, after these changes are made, becomes the isometric drawing shown in Fig. 19*a*.

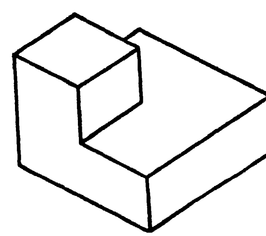


FIG. 19*a*.

There are a number of important principles:

Vertical lines are drawn vertically.

Lines that are parallel in space are parallel in the isometric.

Distances shown in their true length in front and side views are shown vertically in their true length in the isometric.

Distances shown in their true length in front and top views are seen extending to the left at 30° with the horizontal and in their true length.

Distances shown in their true length in top and side views are shown in their true length in the isometric, extending 30° with the horizontal toward the right.

An angle is laid off as in the oblique. Obtain the two lengths at right angles that determine the angle, then lay off these lengths according to the rules for the isometric.

The instructions for making circles in faces not in the front view as given for oblique drawings hold for all circles in isometric drawings. The instruction for irregular points may likewise be used except that it must be changed to conform to the isometric laws for plotting.

If we extend the 30° lines down rather than up, we see the bottom rather than the top of the object; a drawing made this way is said to have "reversed axes."

In dimensioning an object in the isometric we follow in general the rules for orthographic drawings. However, as in the oblique, extra caution is

necessary to show just what the limits are. If practicable, place the extension lines in the prolongation of the object lines.

Also as in the oblique, the guide lines for the lettering should be parallel to the corresponding dimension line and the slope of the lettering should be parallel to the corresponding extension lines.

There is not so much variety in isometric as in oblique. Still, as far as possible, if the isometric is to be employed, use the isometric view that will show the object and its dimensions most clearly. Sometimes the student may be able to use either the oblique or the isometric, whichever will best serve his needs.

REQUIRED WORK: LESSON 19

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

19-1. Compare isometric and oblique drawings.
19-2. Explain how an angle is laid off.
19-3. What distances are shown in their true length in the isometric?
19-4. When would you prefer the oblique and when the isometric if a pictorial drawing was to be made?

Sheet 19-1 (Fig. 19*c*)

19-5. How many tap bolts are used in this block?
19-6. What would be the weight of this block at .26 lbs. per cu. in.?

Sheet 19-2 (Fig. 19*d*)

19-7. State the extreme width of this block.
19-8. What is the area of the lower recess?
19-9. How does this compare with the upper recess?

Sheet 19-3 (Fig 19*e*)

19-10. What is the size of timber joist that this will carry?
19-11. State the breadth of the supporting beam.
19-12. What is the section of steel from which this hanger was made?

Sheet 19-4 (Fig. 19*f*)

19-13. Enumerate the different diameters of hole in this bench block
19-14. State the smallest distance, edge of hole to outside of block.

Sheet 19-5 (Fig. 19*g*)

19-15. How many full-length rafters are shown?
Note: Do not include those for the dormer.
19-16. What is the difference between a hip and a valley rafter?

Sketches

19-17.
19-18. Sketch isometrically the two objects which you did not sketch in your
19-19. last lesson.
19-20.

LETTERING

In Fig. 19*b* is a box title such as is used by many industrial firms. Please copy in ink. If grave faults appear repeat until you can produce an acceptable title.

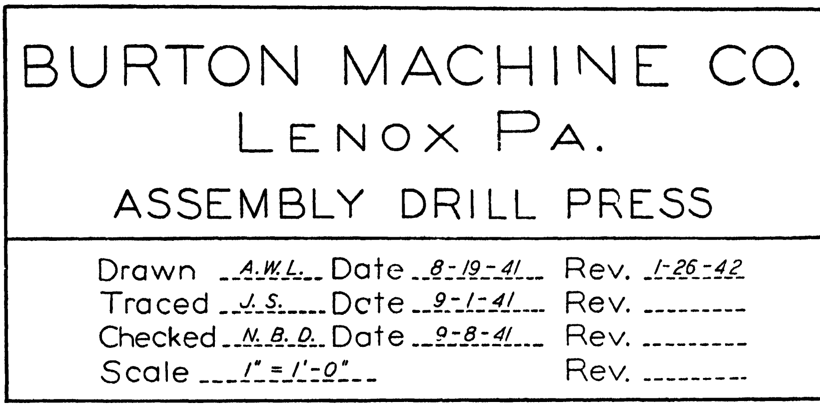


FIG. 19*b*.

SHEETS

All sheets are to be in ink upon tracing cloth. Students who are making good progress can begin to plan to do some of their work directly in ink without first making a copy in pencil.

SHEET 19-1 (Fig. 19*c*)

In Fig. 19*c* are shown two views of a holder for keeping bars in place while ends were being milled. Copy it at a scale of 3″ = 1′-0″, and then

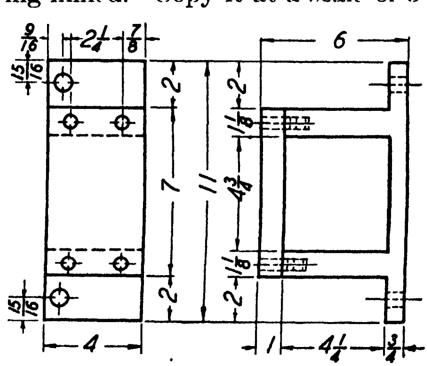


FIG. 19*c*.—A bar holder.

above it draw and dimension the object in the isometric at a scale of 6″ = 1′-0″. Make 6″ the height.

Sheet 19-2 (Fig. 19*d*)

In Fig. 19*d* are shown two views of a base for a jig. Copy them at a scale of 6″ = 1′-0″ and then draw and dimension the isometric of the object.

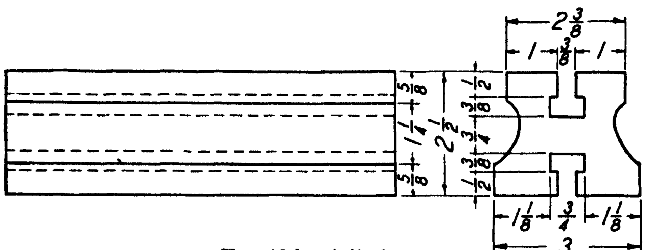


Fig. 19*d*.—A jig base.

Sheet 19-3

Figure 19*e* shows two views of a hanger. This rests upon a central beam and supports a joist on each side.

Draw and dimension the isometric at a scale of 3″ = 1′-0″.

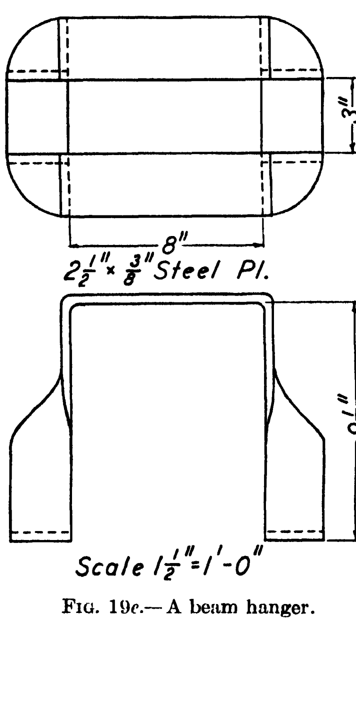


Fig. 19*e*.—A beam hanger.

SHEET 19-4 (Fig. 19*f*)

In Fig. 19*f* are shown two views of a bench block. Copy these drawings with their dimensions, but make the scale full size.

Then draw in the upper part of the sheet, also full size, the corresponding isometric omitting dimensions.

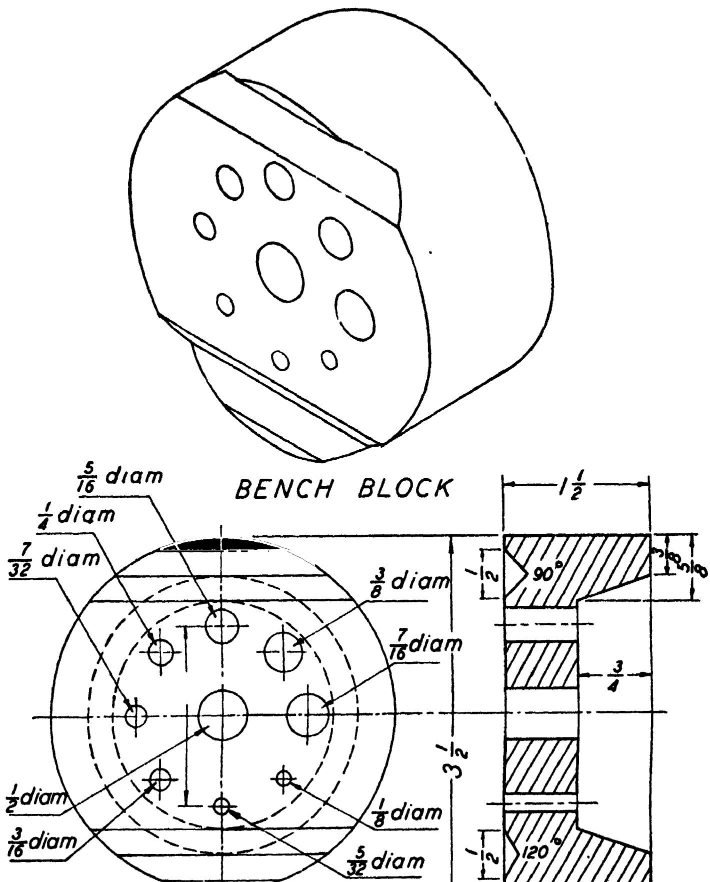


FIG. 19*f*.—A bench block.

SHEET 19-5 (Fig. 19*g*)

Figure 19*g* shows an isometric of the framing for the roof of a house. Copy it, making the size just twice that on your drawing.

This is the end of Lesson 19. There is only one more lesson. Make it your best.

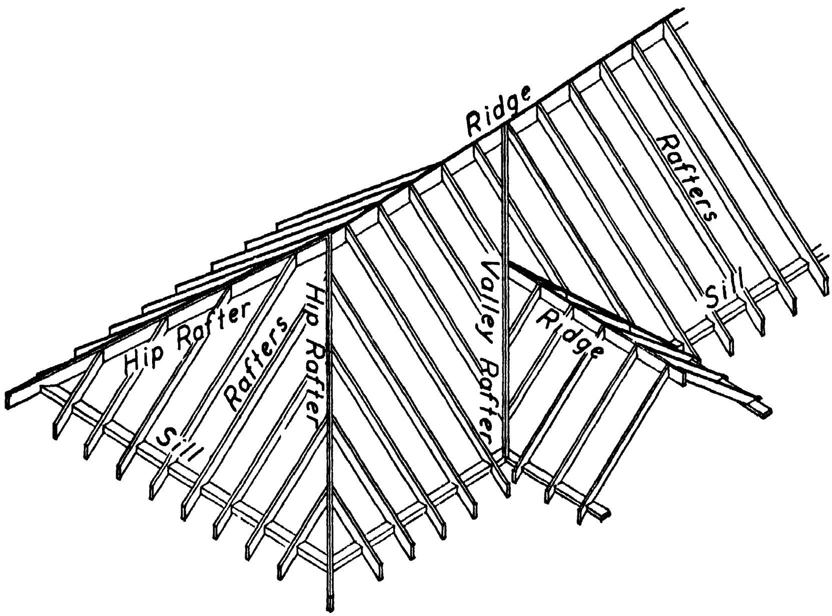


FIG. 19*g*.—The framing for the roof of a house.

LESSON 20

PERSPECTIVE DRAWINGS

A drawing in which the object is shown as it appears to the eye or as it is in a photograph is called a perspective drawing.

The advantage of the perspective is the natural appearance of the object. The disadvantages are the extra labor required to construct it and the fact that measurements in general are not shown to scale. As one might foresee, these advantages lead to its employment in the building and allied

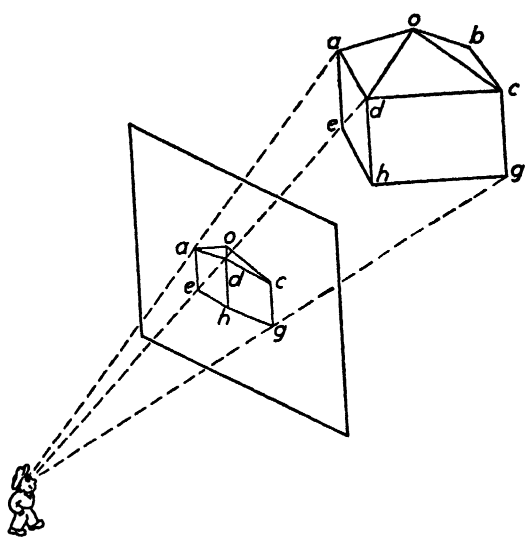


FIG. 20*a*

industries where appearance is very important. The subject is a large one and we can touch only on a few fundamentals.

The methods used are based upon an observer at a certain assumed viewpoint. See Fig. 20*a*. Between this observer and the object is supposed to be a vertical screen. What we draw is really the intersection upon that screen of the rays of light coming from the object to the observer's eye. We will give some helps that shorten the work but the essential principle is to obtain these intercepts; they are quite easily figured out. For example, if the vertical screen is 40 feet away and a pole 15 feet high is 120 feet distant, on the perspective the pole should appear as $\frac{40}{120} \times 15 = 5$ ft.

The position of the eye of the observer is selected by the architect. In general, it should be chosen so that the object will not be unduly distorted. Often, the viewpoint is made the one in which most observers will view the building. Usually, the observer's eye is supposed to see both front and depth. A perspective looking squarely at the front of the building would be much like a front view without the advantages of the latter.

As an example, let us consider the monument of Fig. 20*b*. The top view is revolved to bring the line of sight vertical, while the front view is shown at the left. The latter is used only to get heights. The scale is $\frac{1}{32}'' = 1'\text{-}0''$.

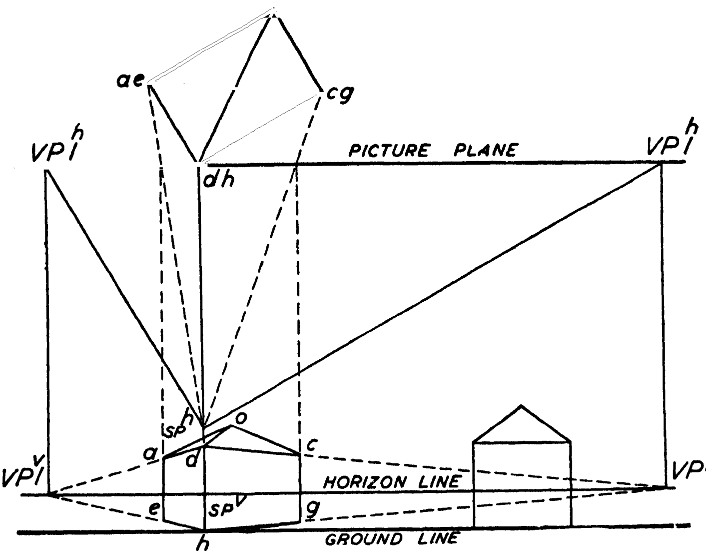


FIG. 20*b*.—A perspective.

The picture plane on which the object is supposed to be projected, is shown and marked. It is drawn perpendicular to the line of sight; the viewpoint marked SP^h in plan is 43 feet in front of the nearest corner of the monument. Let us also specify that the eye of the observer is 6 feet above the base level; that the main part of the monument is 14 feet high while the vertex is 6 feet higher yet.

Now since the corner d is right on the screen, it follows that it will be shown as a full size vertical line 14 feet long at a scale $\frac{1}{32}'' = 1'\text{-}0''$. The line must be vertically below SP^h, through SP^v. Quite clearly the other vertical lines on the monument will make vertical lines on the screen not so large as the one just found. Of course, this might be figured but shorter ways are available. These vertical lines are located in the perspective view directly under their intercept in the plan.

If now the side ad extended a very long distance, the line from SP^h to VP_L^h would represent the line of sight in plan. VP_L^h would indicate its

interception on the screen and VP_L^v would represent it in a front view of the screen. However, it is a matter of common observation that parallel lines appear to meet on the horizon when they are continued a very long distance. It is evident then that all horizontal lines in the face *adeh* meet at VP_L^v (Vanishing Point at the left). Similarly, all horizontal lines in *cdhg* or parallel planes, meet in the front view of the screen at VP_R^v. These two vanishing points enable us to complete the perspective of the rectangular portion of the object.

Sometimes the picture plane is not at a corner nor is there a good starting point. We can illustrate the method then employed in locating *o*, the vertex

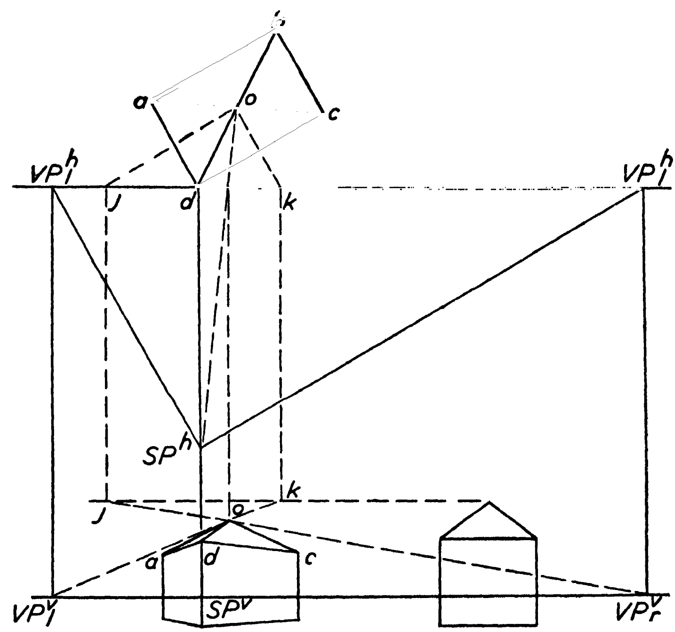


FIG. 20*c*.—Special method.

of the monument, Fig. 20*c*. Imagine that a horizontal line, parallel to one face, runs from *o* to the picture plane; its intercept on the plane would then be at *j* and it would be the full height or 20 feet; but then as one goes back from *j* to the original point, *o*, we are in the same system as *cdhg* and the lines vanish to VP_R^v. However, the actual intercept from *o* can be obtained in the usual manner and the line to the vanishing point determines its height as shown.

Dimensions on perspective drawings are not common. There is a scale for the drawings from which they are made but there is really no scale for the drawing itself.

REQUIRED WORK: LESSON 20

Answer eight questions, make two sketches, do the lettering, and draw one sheet.

20-1. Define the perspective.

20-2. State advantages and disadvantages of the perspective.

20-3. What determines the position of the observer?

20-4. Is it possible to have a length on the perspective greater than that on the original drawing?

SHEET 20-1 (Fig. 20*e*)

20-5. Into how many lengths (panels) is this bridge divided?

20-6. What is the height of the bridge?

SHEET 20-2 (Fig. 10*j*)

20-7. How long is this bridge?

20-8. What is its greatest height?

SHEET 20-3 (Fig. 20*f*)

20-9. State the size of the windows.

20-10. How high is the top of the chimney from the ground?

20-11. What is the pitch of the roof around the chimney? (So many inches vertical to 12″ horizontal.)

SHEET 20-4 (Fig. 20*g*)

20-12. State the height of the base.

20-13. How long is the handle?

20-14. What is the greatest diameter of the jack?

SHEET 20-5 (Fig. 20*h*)

20-15. State the length of the handle.

20-16. Give the three extreme dimensions of the base of the piece.

Sketch a perspective of:

20-17. A monument near you.

20-18. The house where you live.

20-19. The school building in which was held the last exercise that you attended.

20-20. Your borough hall (City Hall).

LETTERING

Letter this title in ink; copy it as closely as you can. If the result is not satisfactory, do not submit it but try it again.

CAR UNLOADER
FOR
GREAT LAKES SHIPPING CO.
CLEVELAND OHIO
Scale 1"=1'-0"   June 1943
R. L. Pierce C. E.

Fig 20*d*.

SHEETS

All sheets are to be in ink upon tracing cloth.

Sheet 20-1 (Fig. 20*e*)

Draw a perspective, an isometric, and an oblique of the bridge shown in Fig. 20*e*. The scale will be $\frac{1}{16}'' = 1'\text{-}0''$ for the latter two and about that for the perspective.

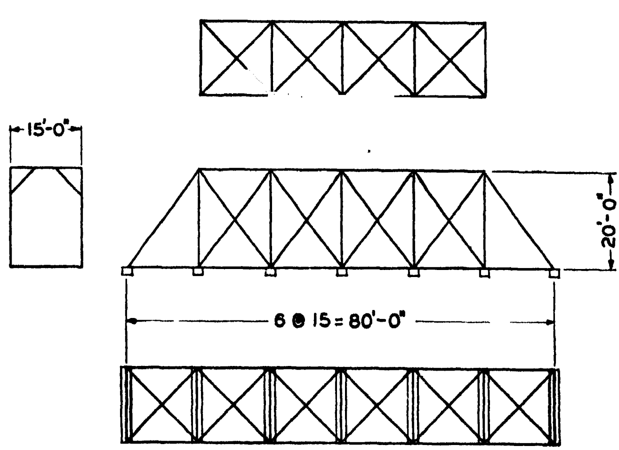


Fig. 20*e*.

SHEET 20-2 (Fig. 10j)

Draw a perspective of this bridge, making the scale about 1/32″ = 1′-0″.

SHEET 20-3 (Fig. 20f)

Draw a perspective of this building, making the viewpoint 66 feet from the picture plane at the front corner at an angle of 120° with the longer

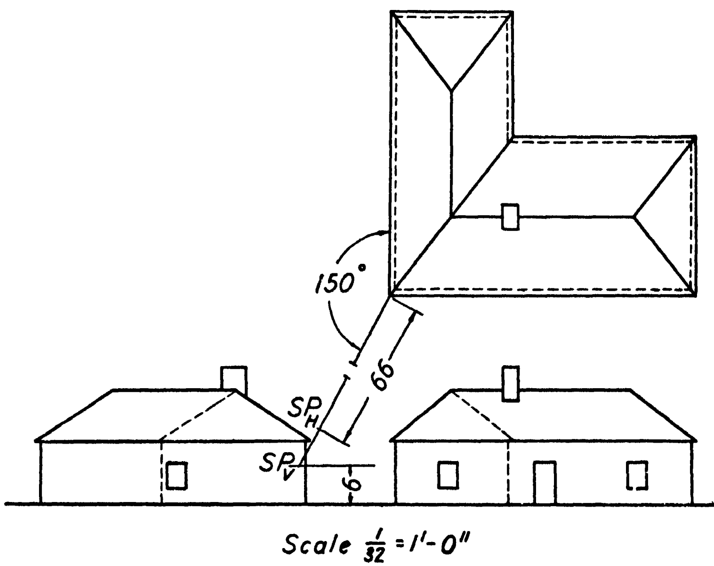


FIG. 20f.

side. The viewpoint is 6 feet above the foundations. W = Window and D = Door. The scale of cut is 1/32″ = 1′-0″, of your work about 1/16″ = 1′-0″.

SHEET 20-4 (Fig. 20*g*)

The pictorial drawing in Fig. 20*g* represents a small machinist's jack. Draw the same full size orthographically. It will be necessary to show the

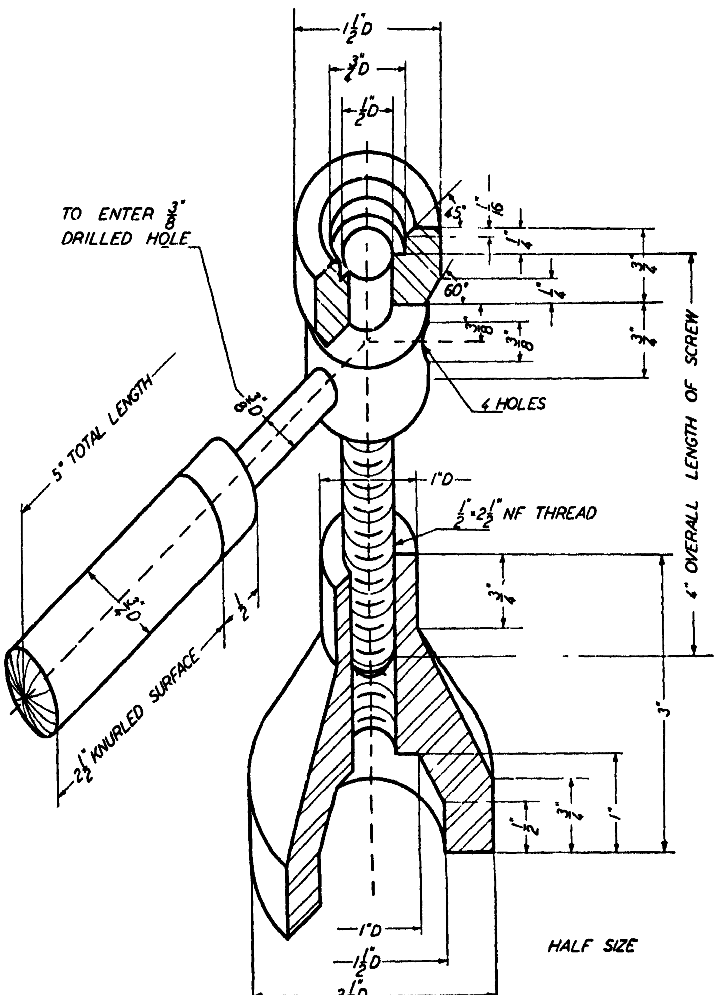


FIG. 20*g*.—A machinist's jack.

handle separately. Because of the fact that all parts are round, one view of each is enough. Dimension.

SHEET 20-5 (Fig. 20*h*)

The drawings in Fig. 20*h* show a vise. Draw orthographic front, top, and right side views at a scale of 6″ = 1′-0″. Dimension.

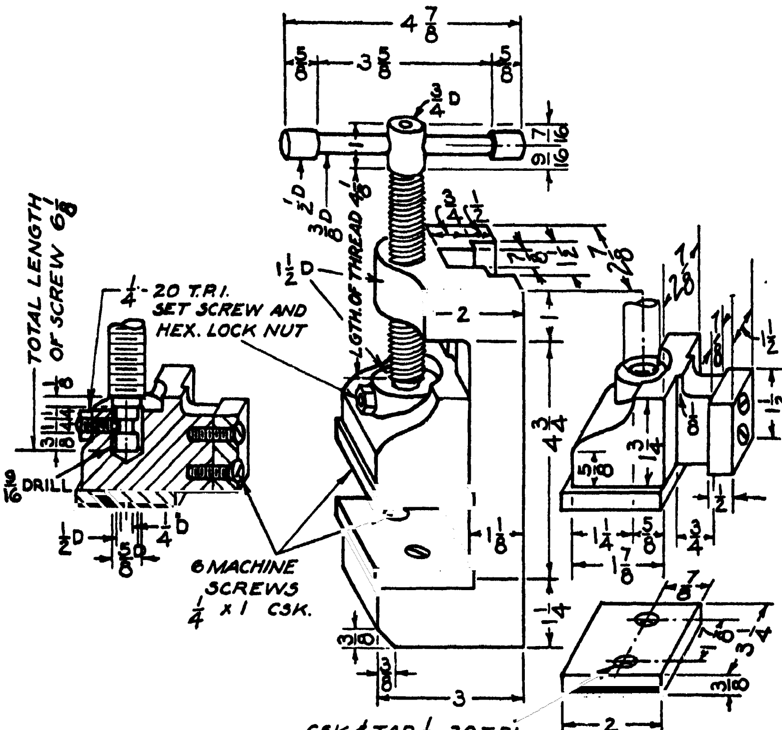


FIG. 20*h*.—A vise.

We have now reached the end, not only of Lesson 20 but of this text. We trust that the instruction has been thorough and that you have benefited.

Let us again emphasize the fact that we have felt obliged to limit ourselves to what can be thoroughly learned in 20 lessons. There is a great deal more to be studied. We hope that you are not satisfied but remain a student, always anxious to learn more about your profession.

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